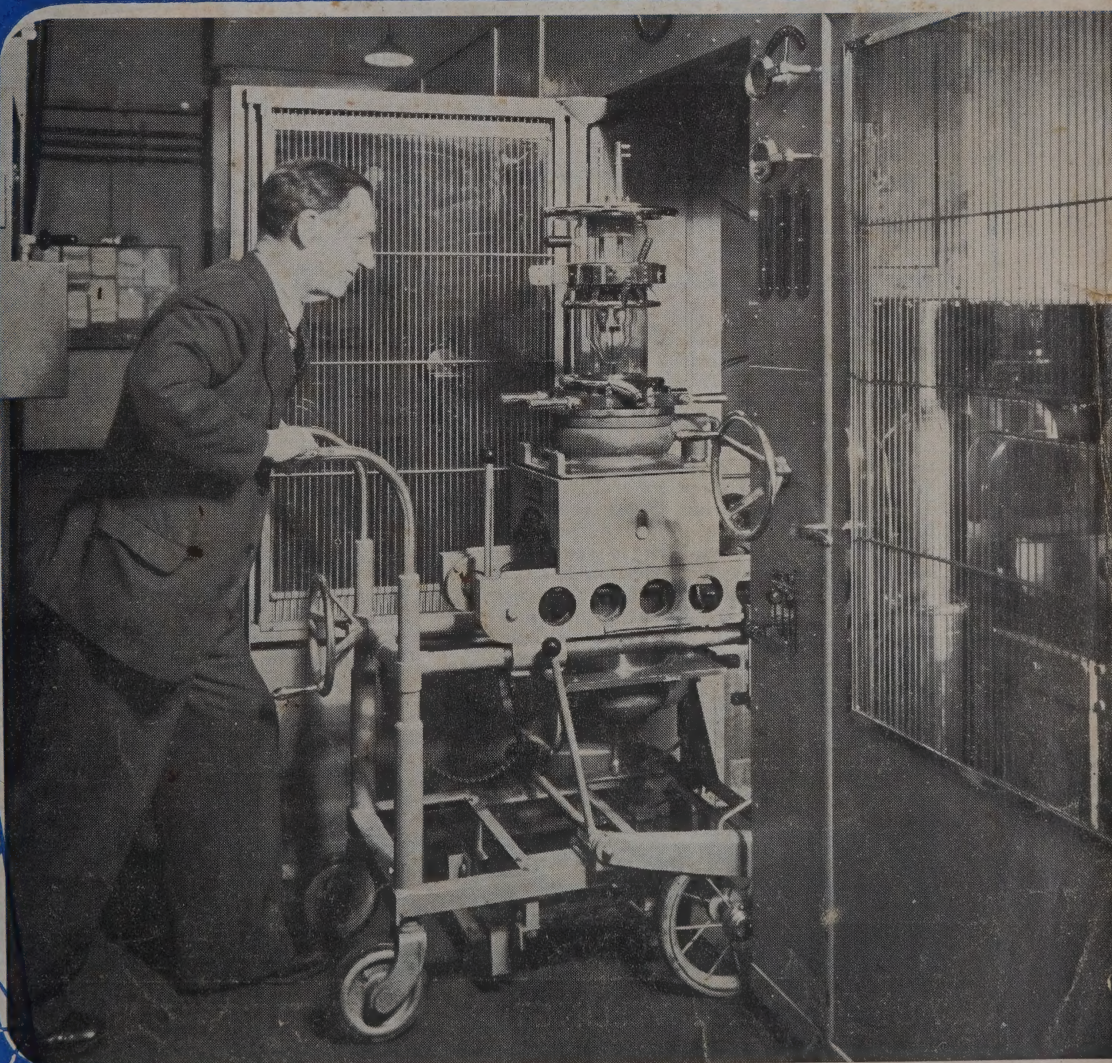
RADIO and ELECTRONICS

ELECTRICITY — COMMUNICATIONS — SERVICE — SOUND



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RADIO and ELECTRONICS

Vol. 3, No. 8 — 1st November, 1948

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OUR COVER:

This month's cover is by way of being a companion to the one we used last month. It depicts one of the valves of the output amplifier, which is mounted on a truck similar to the one used for the tuned circuit and wheeled into position in the transmitter.

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SOME MORE ABOUT FIDELITY OF REPRODUCTION

During the war a very well-known American manufacturer of loud-speakers issued the first of a number of short papers on subjects closely affecting the reproduction of speech and music. In the third of these, which discusses the frequency range and power requirements for the faithful reproduction of music, there are brought to light a number of interesting conclusions, based on some of the most recent American work on the subject. The references quoted are all to data published in various scientific journals between the years 1931 and 1944, so that the statements and deductions made can hardly be criticized on the score of obsolescence.

The subject is a very complex one, and any attempt to draw definite conclusions must be supported by the most rigorous analysis of experimental results if the said conclusions are to have any real value. Factors which must be taken into account include the acuity of hearing, averaged over a representative section of the community, the noise-levels to be found under normal listening conditions, the way in which the acoustic power output of an orchestra is distributed over the whole audible spectrum, and the smallest changes in frequency response that can be observed by the average listener, to mention only a few. In addition to these purely scientific data, more mundane considerations must be brought into the picture. Chief among these is the cost of making improvements in fidelity at any stage.

Perhaps the most interesting results that have come to light as a direct outcome of recent research are those which show just what changes have to be made in the frequency response of a reproducing system in order to effect a noticeable improvement. The writer of the paper quotes the work of Gannett and Kerney, who determined that the smallest downward steps that are detectable by a critical listener are from 15,000 c/sec. to 11,000, from 11,000 to 8,000, from 8,000 to 6,400, from 6,400 to 5,300, and from 5,300 to 4,400 c/sec. That is to say, that if we start off with a system which is capable of reproducing everything up to 15,000 c/sec., and then progressively decrease the width of reproduced band, the critical listener will have only an even chance of telling that any change has occurred at all until the above steps have been made! Most of us, however, are interested in going the other way, in order to realize improvements, and when it is realized that these figures apply only to critical listeners, and not to the average of a large number of listeners chosen at random, the conclusions are all the more striking. The difference that can be expected to be just noticeable to the average listener (that is to say, any one of our friends who we hope will agree with us just how much better our radio-gramophone sounds than any other he has heard) are more nearly *two* steps in the above table. Thus, if we improve our equipment's high-frequency response from 6,400 to 8,000 c/sec., without introducing any more distortion in the process, we can expect the difference to be barely more than just perceptible to our hypothetical friend. Similarly, to effect a very noticeable improvement from 8,000 c/sec., the top reproduced frequency would have to go to the maximum of 15,000 c/sec.! Although similar considerations undoubtedly apply to reproduction at the low end of the scale, too, the experimental results are not so complete. However, as a basis for designing reproducing systems with varying degrees of fidelity, the writer of the paper to which we have been referring has suggested the following eight specifications for reproduced frequency range.

		Cut-off Frequencies	
Band No.	*Classification*	*Low*	*High*
1	High Fidelity	40	15,000
2	High Fidelity	65	11,000
3	High Fidelity	75	8,000
4	Medium Fidelity	90	6,400
5	Medium Fidelity	110	5,300
6	Medium Fidelity	130	4,400
7	Low Fidelity	160	3,600
8	Low Fidelity	200	3,000

When the question of cost is also brought into consideration, we find that from a high-frequency limit of 5,000 c/sec. the cost of raising the upper limit of response is approximately proportional to rather more than the square of the limit frequency. For example, it costs almost ten times as much for a receiver whose response is flat within 2 db, up to 10,000 c/sec. as does a receiver whose top frequency is 5,000 c/sec. After this, the rate of increase slows down somewhat, but to reproduce everything up to 15,000 c/sec. is estimated to cost 25 times as much as the 5,000 c/sec. system!

Of course, there are a number of factors that are apparently taken for granted in this analysis. For one, the question of allowable distortion has not been mentioned. It is safe to assume, however, that this has been taken into account, for it is well enough known that the more the frequency response is extended, the less is the tolerable distortion. In fact, it seems probable that a very large proportion of the sharply-rising cost is due to this very factor.

The above figures have been given as some sort of authoritative guide to those interested in quality reproduction, to assist them in estimating where to stop trying for more extended high-frequency response, and to start concentrating on lack of distortion throughout the system.

A NEW VOLUME EXPANDER CIRCUIT WITH LOW DISTORTION

In spite of criticisms levelled at them from time to time, volume expanders can add considerably to the realism of recordings of music, and are a source of much entertainment, both to experimenters and music-lovers. The circuit described in this article uses three valves, all of them triodes, and avoids the chief fault of those designed to work by varying the gain of a variable-mu valve. The principle of operation is to some extent new, and should be of interest to a number of readers.

INTRODUCTION

It is well known in these enlightened times, when the processes of the recording and transmission of sound are understood by quite a large proportion of those interested in the electrical reproduction of recordings, that perhaps the most important technical defects of modern recordings are those caused by the inability to record the softest and loudest passages of a piece of music in their correct proportions. That is to say, the loudest piece of a recording is not loud enough compared with the softest bit of the same recording. Recording engineers know this, for in the interests of producing a record that is satisfactory at all, this fault has to be introduced purposely.* While it is true that present-day recordings are better in this respect than are ones made several years ago, there is still room for improvement; in the so-called "transcription" recordings used by, and made specially for, broadcasting stations, the range of volume to be found is considerably better than occurs on the commercial gramophone records that can be bought in the shops. However, it is not practicable to use the devices which allow transcription records to be made better than commercial ones, because of the special equipment that is required at the reproducing end. Nor will it be possible to do so until a standard method of increasing the volume range is agreed upon internationally and is put into practice. Thus, we can expect no major improvements in the volume range possessed by our ordinary commercial recordings for a considerable time, unless some vastly superior pressing material is discovered at an early date. This being the case, there is still a need for some device which can be used while the record is being played and which will make the louder parts of the record louder still, or the softer parts softer still, which is the same thing. Such a device has been known for some years as a volume expander, and a great variety of circuits, ranging from very simple and inexpensive ones to others containing many valves and a multitude of controls, have been developed from time to time.

OPERATION OF VOLUME EXPANDERS

By far the most expanders use valves to obtain a variation of amplification that depends on the strength of the audio signal from the record. This is done by a kind of inverted automatic volume control, in which the audio signal is rectified, to obtain a D.C. control voltage. This control voltage is then applied to the grid of an audio amplifier using a variable-mu valve, and it is applied in such a way that the greater the control voltage, the greater the amplification of the controlled stage. The latter can use a variable-mu pentode, in which both audio input and control voltage are applied to the control grid, or it can use a 6L7 type of tube, in which case the audio signal and the control voltage are applied to different grids.

In either case, the use of a variable-mu tube introduces appreciable distortion unless the input signal is limited to a very small value. There are also certain other disadvantages in the scheme which have been dealt with in the article referred to.* The distortion aspect, however, is the most serious one, and these days, when the standard of equipment in use by most enthusiasts is of much higher quality than was the case a few years ago, the introduction of distortion can be tolerated even less than ever.

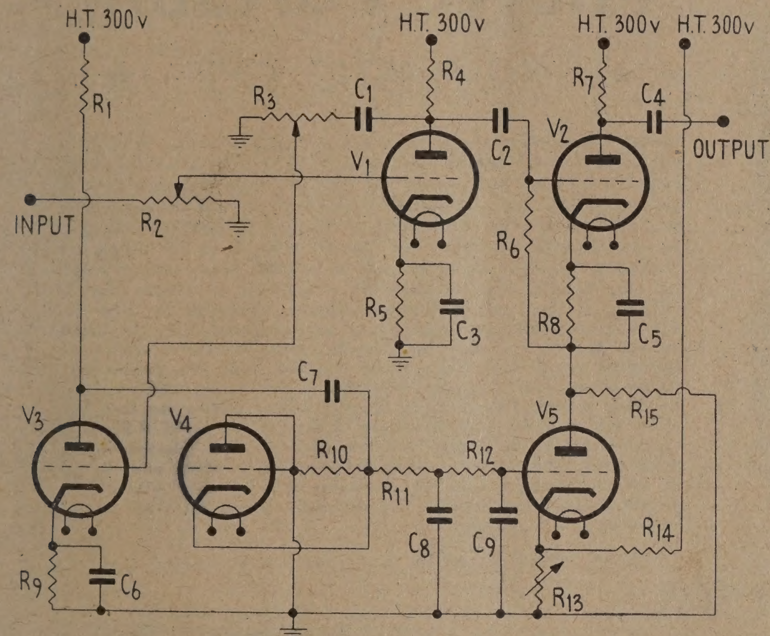
It is with this idea in mind, then, that the present circuit was developed in our laboratory. It makes no claim to being the best circuit yet, or anything of that nature, but its performance is definitely superior to that of any circuit using the 6L7 or other variable-mu valve as the controlled amplifier. For one thing, it is possible—and desirable, too—to operate this new circuit with an input of several volts rather than the small fraction of a volt that must not be exceeded in using the other type. Also, tests with an audio oscillator and an oscilloscope showed that the distortion was negligible, and listening tests with a high-quality amplifier revealed that the quality was indistinguishable from that of the amplifier itself, when the expander was in circuit.

NEW PRINCIPLE USED HERE

In the present design, a principle has been called into play which though not new for other purposes, has not yet been applied to the problem of volume expansion. It is that the gain of an amplifier can be controlled by varying the degree of negative feedback applied to it. Thus, our expander works in the following way: A triode is connected as an ordinary resistance-coupled amplifier stage, with cathode bias, and a load resistor in the plate circuit (V_2 in the circuit diagram). Now if such a stage has a large resistor or indeed a resistor of any value, connected between the cathode resistor and earth, this resistor becomes part of the plate load, and since it is in the cathode circuit, it is also part of the grid circuit at the same time. This being the case, the extra resistor causes a portion of the output voltage to be applied to the input circuit. Also, the polarity of the voltage thus fed back is such that the feedback is negative. If the extra cathode resistance is made equal to the plate load resistor, we have the well-known phase-splitter circuit in which one output is taken from the plate, and the other from the high end of the cathode load resistor. In these circumstances, the gain of the valve from grid to plate is a little less than one. If, on the other hand, the cathode load resistor is made smaller, the amount of negative feedback is decreased, which results in an increase of gain from grid to plate. This is the gain-variation principle used in the expander. How, then, is it put to use? Simply by using a valve, V_5, as the variable cathode load resistor, and by using the control voltage to vary its plate resistance.

We are now in a position to examine the functions of the whole circuit. V_1 is a conventional amplifier stage. Its output is fed first, to V_2, the stage whose gain is to be controlled, and simultaneously to V_3, the first valve

in the control circuit. The output of the expander is taken from the plate circuit of V_2. The control circuit comprises V_3, V_4, and V_5. V_3 is also a straight amplifier, its input voltage coming from the output of V_1, and being controllable by means of the potentiometer, R_3. The output of V_3 goes to the cathode of V_4, which is connected as a rectifier, so as to give a positive D.C. control voltage. The circuit of V_4 is that of a simple shunt rectifier, the only departure from the normal being of cutting down the number of valves used in a circuit unless there is very good reason for doing so, either by way of economy, or because the job can be done as efficiently with fewer. Before the days of double triodes, the circuit would certainly have been an expensive one to build, but the ubiquitous 6SN7 enables it to be put together with only three valves, which is no more than most expander circuits use. The recommended grouping of the sections is given in the component list. As for V_3,



COMPONENT LIST

R_1, R_4, R_7, R_{10}, 100k.
R_2, R_3, 1 meg. pot.
R_5, 5k.
R_6, R_{11}, R_{12}, 500k.
R_8, R_9, 2k.
R_{13}, Rk. w-w pot.
R_{14}, 50k., 2w.
R_{15}, 125k.
C_1, C_2, C_4, 0.05 μf.
C_3, C_6, C_5, 25 μf. 25v. Electro.
C_7, 0.02 μf.
C_8, C_9, 0.1 μf.
V_1, 6C5.
V_2, V_3, V_4, V_5, 6SN7.

that the plate is grounded and the signal is fed to the cathode. This gives the positive-going D.C. output voltage. The rectifier load resistor is R_{10}. The network R_{11}, R_{12}, C_8, C_9 is a smoothing filter whose job is to remove the audio ripple from the output of the rectifier, so that there shall be as little audio voltage as possible in the D.C. control voltage fed to the grid of V_5, which is the control tube. The latter is normally biased to cut-off, so that its plate resistance is very high. Thus, with no control voltage into the grid of V_5, there is a large resistance between cathode and earth for V_2. Its gain is therefore very low. When an audio signal comes along, it is rectified by V_4, a positive control voltage is applied to the grid of V_5, with the result that its plate resistance drops and the gain of V_2 increases. Further, the stronger the audio signal into the control circuit, the larger will be the control voltage, and the higher becomes the gain of V_2. Our required operating conditions are therefore fulfilled, in that the louder the audio signal into the expander, the greater the amplification. Thus, the situation prevails that we have attempted to achieve.

CIRCUIT DETAILS

The above paragraphs explain in broad outline how the expander works, but there are a few details that should be gone into before one attempts to build the circuit and operate it.

First of all, why is V_3 necessary, and does not the circuit call for rather a large number of valves? Answering the second of these questions first, it should be pointed out that we have never followed the principle this was included so that the whole circuit would be suitable for almost any gramophone pick-up that might be used with it. For supposing that the control circuit does not have enough gain, the full expansion capabilities of the circuit would not be realized. For the average pick-up, the control chain has more than sufficient gain, but there is no disadvantage in this, since the input potentiometer R_3 is the control by means of which the degree of expansion is varied, and a very smooth control of expansion is possible. Again, it might be questioned as to the necessity for V_1 where the pick-up has a large output, of, say, a volt or two. There is a very good reason for the inclusion of V_1, too. It is this, that V_2 is worked with its whole grid circuit "up in the air," making the valve particularly susceptible to the hum that is always present in greater or lesser degree owing to the use of A.C. on the heater. It will be remembered that when the phase-splitter circuit is used, it is always placed directly in front of the output tubes, so that it is handling a signal of not less than several volts. Heater-cathode hum is the reason for this, and since our circuit is essentially the same, precautions must be taken so that the controlled stage is worked at a respectably high signal level, too. Hence the inclusion of V_1, which otherwise could be dispensed with in some circumstances. The control R_2, at the input of V_1, is the main gain control, about which we will have more to say under the heading of "Operation." Now, turning to the circuits of V_2 and V_5, there are a few points that require mention. R_8, it will be noticed, is bypassed by a 25 μf. condenser, and is the normal bias resistor. The cathode load resistor is

made up of the control valve, V_5, which is shunted by R_{15}, of 125k. The purpose of this resistor is not immediately obvious, but if it is not included, the degree of expansion that can be obtained is not as great. This is because of the very high plate resistance of V_5 when it is close to cut-off. Also, the behaviour of the controlled stage tends to be erratic under some conditions if R_{15} is omitted.

It was mentioned above that V_5 is biased almost to cut-off in the absence of an audio signal which produces a control voltage from V_4. Under some conditions, namely when the type of recording being played consists preponderately of soft passages, with only occasional loud ones that need expanding, it is an advantage if the expansion does not start until a pre-determined level is reached. In other words, a voltage delay is required so that the control voltage has to build up to the pre-determined figure before any expansion takes place. This is easily brought about with the present circuit by biasing V_5 *beyond* cut-off in the absence of a signal. Thus, supposing V_5 were biased 2 volts beyond cut-off, it would be necessary for the control voltage to reach +2 volts before any expansion set in. However, there is a certain amount of threshold effect inherent in the circuit, even with V_5 not biased beyond cut-off, because the first volt or two of control on its grid has much less effect than the next few volts. The provision of a delay like this is analagous to the delay voltage used in most A.V.C. systems. If desired, R_{13} can be brought out to the front panel of the expander, but it is recommended that it be made pre-set, since its operation is unavoidably noisy, and in any case it can be dispensed with altogether except in the initial adjustment of the system.

It will be noted that the coupling condenser C_7 from V_3 to the rectifier is only 0.02 μf. This is not a mistake, and its value should not be increased. Its purpose is to limit the low-frequency response of the rectifier and so to prevent very low frequency rumble, or isolated low notes in the music from operating the expansion. It also has a desirable effect in aiding the prevention of audio feed-through from the control circuit. It is not possible to filter the D.C. control voltage as thoroughly as could be desired, because so doing causes a time delay in the operation of the expansion. When the rectifier conducts, it does so instantaneously, and immediately produces the control voltage at the junction of R_{10} and R_{11}. This voltage, however, is not immediately applied to the grid of V_5, because the filter circuit contains two condensers which have to be charged by the diode before the voltage across them reaches that provided by the diode. There is thus a time delay of an appreciable fraction of a second before the gain is increased. This delay is clearly undesirable, as if the loud passage to be expanded itself lasts only a fraction of a second, then the expansion does not take place at all, and what is more, the gain of the amplifier is increased *after* the loud passage has gone, and works on the following piece of music, which possibly should not be expanded at all. However, a certain amount of time delay is unavoidable, since it is absolutely imperative that the control voltage should be filtered. The degree of filtering given in this circuit is adequate, especially when the small coupling condenser is used. Needless to say, the filtering becomes less effective the lower the frequency, and this is an added reason for restricting the response at the rectifier.

OPERATING THE EXPANDER

One of the criticisms most often levelled at volume expanders is that a certain amount of trouble needs to be taken by the operator in order to get the best out of them. This is certainly true, but to our way of thinking is hardly a valid criticism at all. What has to be watched with most of them is that the input level is not more than a very slight amount, in order to prevent rather distressing distortion. This circuit largely overcomes this requirement, but even so a certain amount of care is necessary. However, there is a very easy method of ensuring that the expander does not become overloaded, and that is simply to turn up the amplifier main gain control quite high, and then use R_2, the expander input volume control, as the volume control for the whole outfit. This ensures that V_1 and V_2 are not overloaded. V_2 will handle quite large signals without distortion, because of the negative feedback that is present at all times, even when the gain is at maximum, so that V_1 becomes the most critical link in the chain. However, the system recommended will obviate any trouble from this cause.

Once it has been learned by experience with one's own pick-up and amplifier what the best settings are for the input control and particularly for the amplifier's main gain control, all that remains to be done is to set R_{13}. The way to do this is to connect a voltmeter between the plate of V_5 and earth. The meter should be not less than 1000 ohms per volt, and should be set to its 250-volt range, or to a higher one. Otherwise the meter resistance will have some effect on the operation. R_{13} is then adjusted, with no signal into the expander until a voltage of between 100 and 120 is read. The control can then be left set. In general, the resistance of R_{13} will be about 2000 ohms when this condition is reached. It would be entirely practical to make R_{13} a fixed resistor of this value if a threshold control is not wanted.

The expander is now ready to go. At first it is a good plan to leave the meter connected as described, as the expansion shows in the fluctuation of plate volts at the plate of V_5, and gives a good idea of how the device is functioning. First of all, a suitable record should be chosen. An orchestral record which has considerable light and shade, and preferably one in which the strings are prominent, will be found the most suitable for demonstrating the effectiveness of the expander. First of all, subdue the temptation to play it through with the expansion control "flat out" and play it with the expansion control at zero. This is for the purpose of making sure that the amplifying section is working properly, and that there is no distortion. The first playing can also be used to ensure that the main amplifier is being run well within its capabilities, and has plenty of reserve power left for when the expander is brought into action. Next, the loudest part of the record is played, and while it is running, the expansion control R_{13} is advanced. It should be possible to make the loudest passages swing the voltage at the plate of V_5 down to 25v. or so, but in general this represents much more expansion than can be tolerated. Set the control, therefore, so that the plate voltage of V_5 swings to about 50v. on peaks of the music. Having done this, and at the same time made sure that the main amplifier is still running within its capabilities on these peaks, one can sit down quietly and listen to the record played right through, without any of the control having been shifted. Now comes the acid test. The expansion control is turned right off, and the record is played again. It is this time that the full effect of the expansion is felt for the first time. After this, one can experiment with different settings of the expansion control until the best setting is found for the record being played. A good test for this is that with a record whose surface noise is low, one should not be able to hear the expander "breathing." That is to say, one should not be able to hear the noise

(Concluded on page 48.)

PREDICTIONS FOR THE WORKING OF LONG-RANGE RADIO CIRCUITS ON AMATEUR FREQUENCIES

NOVEMBER, 1948

These frequencies are based on world charts of Maximum Usable Frequencies, prepared and issued by the Australian Radio Propagation Committee and supplied to "Radio and Electronics" by courtesy of this body and the New Zealand Department of Scientific and Industrial Research.

Contrary to normal commercial practice in the use of ionospheric predictions, the times given are derived from the Maximum Usable Frequencies, directly, and not from Optimum Working Frequencies, which are 15 per cent. lower.

The circuits are considered workable (a) if the band in question is below the M.U.F. at the time considered, and (b) if the said band is not lower than 65 per cent. of the M.U.F. If (b) is not satisfied, communication is unlikely, not because the frequency is not reflected by the ionosphere, but because the power available to amateurs is too low to overcome absorption in the ionosphere under these conditions.

Where the word "doubtful" appears in the tables, it indicates that between the times so labelled, the band is a little higher than the M.U.F. There is thus a possibility of effective communication on days when the actual M.U.F. is only slightly higher than that predicted.

All circuits have been assumed to start in Wellington. This creates the possibility of some slight error for other starting points, but this is of minor importance only, and does not justify the multiplication of the work involved.

ENGLAND

	N.Z.D.S.T.
Wellington to Liverpool:	
(*a*) North Route:	
14 mc/sec.	1830 — 0730
30 mc/sec.	Nil
(*b*) South Route:	
14 mc/sec.	1800 — 1030
30 mc/sec.	Nil

U.S.A.

Wellington to New York:	
14 mc/sec.	2330 — 1630
30 mc/sec.	0600 — 1200
Wellington to New Orleans:	
14 mc/sec.	2330 — 2030
30 mc/sec.	0600 — 1230
Wellington to Washington:	
14 mc/sec.	0300 — 2000
30 mc/sec.	0530 — 1500
Wellington to San Diego:	
14 mc/sec.	0200 — 2200
30 mc/sec.	1530 — 1500
	1500 — 1730 (doubtful)

CANAL ZONE AND SOUTH AMERICA

Wellington to Panama:	
14 mc/sec.	24 hrs.
30 mc/sec.	0730 — 1430
Wellington to Pernambuco:	
14 mc/sec.	24 hrs.
30 mc/sec.	Nil
Wellington to Buenos Aires:	
14 mc/sec.	24 hrs.
30 mc/sec.	Nil

AFRICA

	N.Z.D.S.T.
Wellington to Dakar:	
(*a*) North Route:	
14 mc/sec.	1800 — 1130
30 mc/sec.	1900 — 2130
(*b*) South Route:	
14 mc/sec.	24 hrs.
30 mc/sec.	Nil
Wellington to Capetown:	
14 mc/sec.	24 hrs.
30 mc/sec.	Nil
Wellington to Aden:	
14 mc/sec.	24 hrs.
30 mc/sec.	1300 — 1800

INDIA

Wellington to Karachi:	
14 mc/sec.	24 hrs.
30 mc/sec.	1530 — 1800 (doubtful)
Wellington to Colombo:	
14 mc/sec.	24 hrs.
30 mc/sec.	Nil
Wellington to Calcutta:	
14 mc/sec.	24 hrs.
30 mc/sec.	1230 — 1830

ASIA

Wellington to Hong Kong:	
14 mc/sec.	24 hrs.
30 mc/sec.	0900 — 1830
Wellington to Singapore:	
14 mc/sec.	24 hrs.
30 mc/sec.	1400 — 1700

PUBLICATIONS RECEIVED

VERY HIGH FREQUENCY TECHNIQUES

Vols. 1 and 2

By the Staff of the Radio Research Laboratory, Harvard University. Publishers, The McGraw-Hill Book Co. Inc.

These two volumes, which the publishers have very wisely issued simultaneously, form yet another of the contributions to radio frequency literature which have arisen as a direct result of war-time research and development. Unlike most of the others, however, the subject-matter of the volumes springs directly from the work of a number of men who, as a team, were entrusted with one particular phase of the United States' national research programme, namely, that of radar counter-measures. Lest it may be inferred that a project of this circumscribed nature would necessarily give rise to a mass of highly specialized results, of not much interest to radio engineers in general owing to the limited field apparently involved, it should be pointed out that such is by no means the case. The truth of the matter is that the field of radar counter-measures was by no means a circumscribed one, as will be realized by any worker who had anything to do with radar or with counter-measures during the war. What makes these books of probably greater interest to the general radio engineer than most others which have been published since VJ-day is the fact, stated by Dr. F. E. Terman in his foreword, that "The Radio Research Laboratory was unique in being the only large temporary war-time laboratory concerned in a major way with the extension of continuous wave techniques to the high radio frequencies used in radar work. Such techniques were the basis of most pre-war activity in radio below 100 mc., and it is expected that they will be important in the exploitation of the higher frequencies that the war has made available." While the pulse techniques employed in radar and in a number of associated devices will be of increasing peace-time importance, there seems no doubt that continuous wave work on the decimeter and centimetre wavelengths will ultimately assume an importance which it does not possess to-day, if for no other reason than the existing overcrowding of that part of the radio frequency spectrum which is now used with comparatively little technical difficulty. It appears, then, that the full importance of this work will not be felt for a few years at least, and since peace-time development in such fields is very much slower than that during war, it does not seem likely that the present volumes will easily become outdated.

Such a fate could hardly occur in any case, for much of the material is new, in the sense that it has not been previously published except in secret war-time Reports. Much of it is also of fundamental interest. For example, Chapters 13, 14 and 15 form an admirable review of the whole subject of power generation at very high frequencies, in addition to presenting much practical information on the more advanced forms of V.H.F. negative-grid oscillators.

Perhaps the best way of describing the scope of these volumes would be to give a complete list of the 35 chapter headings! Among these one finds such diversified subjects as Broad-band Antennas (very complete, this chapter, including as it does a treatment of the directional properties of wave-guide energized horns and apertures); Ultra-high-frequency Measurements; four chapters on direction finding at frequencies between 50 mc/sec. and 10,000 mc/sec.; The Modulation of High-powered Oscillators; Continuous-wave Magnetrons (three chapters); Tuners for Microwave Receivers; Local Oscillators, with one chapter devoted to general considerations and butterfly circuit oscillators, and a second on reflex oscillators, to mention only a few.

Of particular interest to those engineers who are faced for the first time with the practical application of some of the more recently developed types of tube will be the many excellent cut-away diagrams showing the construction of coaxial line oscillators for "lighthouse" tubes, and illustrating the physical form taken by centimetre equipment generally. Most books dealing with modern V.H.F. techniques content themselves with giving schematic diagrams only. These diagrams, while they serve a useful purpose in helping to explain the operation of unfamiliar devices, seldom give much idea of the practical implications of such equipment. The present volume contains a wealth of perspective and exploded views of typical pieces of equipment which are also very adequately discussed from the theoretical point of view, thus adding enormously to the practical value of the book. In addition, the subjects that are dealt with from theoretical considerations are not simply those of fundamental importance. Nevertheless, the bulk of the mathematics to be found consists only in stating formulae that have been developed to meet the needs of designers. In this way, the treatment throughout has been done with an eye to the engineer's requirements rather than those of the teacher or the scientist. These volumes should therefore find an honoured place in the libraries of all those interested in radio frequency work.

—W.D.F.

* * *

PULSE GENERATORS

Edited by G. N. GLASOE and J. V. LEBACQZ.

Publishers, Messrs. McGraw-Hill Book Co. Inc.

This book is No. 5 of the important series of 28 written by the staff of the M.I.T. Radiation Laboratory, as a record of the immense quantity of valuable development work in radar carried out during the war years. The production of these 28 volumes is a great and worthwhile undertaking which is not yet quite complete; the volume under review is a worthy member of a distinguished family, and provides a very thorough and complete treatment of the subject.

The foreword states that the work described is the collective result of work done at many laboratories, both in America and in British countries. This was no doubt the objective but in fact information from British sources is very slightly quoted—no reference at all is made to the excellent series of papers collected in the I.E.E. Radiolocation Convention. In fact, very little difference would be made to the book if work acknowledgedly or completely British were completely omitted; the impression thus conveyed of the relative importance of American and British development effort can hardly be correct. However, so much work was done on all sides that the writers can perhaps be forgiven some inability to see the wood for the trees.

The book is divided into three main parts, preceded by an introduction which establishes in simple terms the fundamental principles of pulse generation and compares the modes of operation and capabilities of the two main classes: those depending on high-vacuum tubes acting as class C amplifiers, and those in which the pulse is formed by the complete discharge of a transmission-line type of network by means of a spark-gap or a thyratron. Briefly, the line-type pulse generator is the more efficient, operates from a lower voltage supply, and can usually be designed for smaller size and weight. On the other hand, the hard tube type gives a better pulse shape, is

uncritical in load matching, is free from jitter, and permits easy change of pulse duration by switching. Parts I and II deal with these two main types and Part III deals with pulse transformers, which may be used with either type, though more commonly with the line-type where impedance matching between the load and the artificial transmission line is important.

Part I contains Chapters 2 to 5 dealing with: The basic output circuits of the hard tube type; the characteristics required of the tube; and the circuits used to drive the output stage. The operation of the output circuit is analysed by regarding the magnetron as presenting a high—or infinite—resistance up to a critical voltage, and a lower dynamic resistance, usually of the order of a few hundred ohms, above that voltage. Agreement between calculated and measured current and voltage pulse shapes is shown to be good. A knowledge of Laplace-transform methods is necessary for the full understanding of the calculations, but the results of calculation are quite clear and should be most valuable for their own sakes. Chapter 5 brings the subject back to the practical plane by giving circuit details, and an account of the operation, of three actual designs of hard tube pulse generators.

Part II comprises Chapters 6 to 11. Chapter 6 deals with the design and characteristics of the various types of pulse-forming networks commonly used. In Chapter 7 the effect on output of the non-linear load presented by a magnetron, and of impedance mismatch, losses and strays, are considered. Chapter 8 is devoted to the various types of devices used to discharge the line, viz, rotary spark-gaps, fixed spark-gaps (including trigatrons), and hydrogen thyratrons. Chapter 9 deals with the methods of recharging the line after discharge, and dwells at some length on the method of resonant charging, either with D.C. or A.C. supplies, to obtain a potential on the line two or three times that of the supply. The overall performance of the pulse generator as affected by the various components and by variations of load impedance, e.g., from magnetron sparking or mode-changing, is discussed in Chapter 10. Chapter 11 describes examples of up-to-date technique. As with Part I, calculated and measured characteristics are illustrated and compared in a full and convincing manner.

Part III, comprising Chapters 12 to 15, deals fully with the design of pulse transformers, from the elementary theory to consideration of suitable materials and methods of construction, and includes details of a considerable range of practical types.

Appendices provide a description of pulse-measuring techniques, and a discussion of the significance of pulse duration and amplitude. A valuable list of symbols is included, probably of even more use to the multiplicity of authors than to the reader, and a good index.

The high level of publication set by this publisher is well maintained; it is of interest to note that in 1958 the copyright will lapse and the work will "become part of the public domain."

—A.G.B.

A Five-inch Oscilloscope Employing Unit Construction

In an Editorial last month we had something to say on the usefulness of the simplest oscilloscope, namely, one which consists only of the cathode ray tube, its power supply and centring circuits. This article is the first of a series describing an oscilloscope in which the tube is built as a self-contained unit, and the time-base and amplifiers form a separate unit. This makes for ease of construction, and for extreme ease and flexibility of operation.

INTRODUCTION

To those who may have read the Editorial in last month's issue of *Radio and Electronics,* not much will be needed by way of introduction, but for the benefit of those who have not, it may be as well to outline the purpose and the ideas underlying the design we are about to describe.

In the May, 1946, and succeeding issues, we published the design of a five-inch oscilloscope for general-purpose use. This circuit had quite a vogue at the time, and has recently had a new lease of life, due to the release at very cheap prices of war surplus C.R.T.s. It was intended to duplicate the performance of commercial instruments which include a linear time-base and amplifiers for both horizontal and vertical deflection. In this aim it succeeded admirably, as evinced by the numbers that were built, and it was particularly attractive by reason of some of the advanced design features that were incorporated—features that are not possessed by even high-priced commercial instruments. Nevertheless, there are many purposes for which a 'scope of this general nature is not particularly suited. Among them is the display and measurement of modulation patterns. In this application, it is necessary to place an R.F. signal on one pair of deflecting plates, and in a 'scope which has amplifiers permanently connected, this cannot be readily done, since the amplifier has first to be disconnected. In the majority of cases no provision is made at all for direct connection to the deflecting plates, so that it would be necessary to take the instrument out of its case and temporarily "haywire" a connection, after unsoldering the amplifier output lead or leads. Again, when an audio amplifier is to be tested for distortion, the best way of doing this is to put the output voltage on one set of plates, and the input voltage, or an amplified version of it, on the other set. The picture is then a straight line or an ellipse if no distortion is present, and deviates noticeably from these forms as soon as distortion occurs. Incidentally, it is possible to perceive distortion of the order of 0.5 per cent by this means. Now, according to circumstances, this test may require the use of an amplifier for one pair of plates, but not for the other, or it may need amplifiers for both X and Y axes. In any event, it is best done without any 'scope amplifiers at all, if this is possible, because it is very important to keep out all possible distortion from them. Unless the 'scope has provision for disconnecting the internal amplifiers it may not be possible to conduct the test in the most desirable fashion. These two examples are given from a number which could be cited in favour of a 'scope which can be used with or without time-base and amplifiers. Also, since these and many other uses of the oscilloscope do not need any auxiliary gear, there should be a real need for an instrument which contains nothing more than the cathode ray tube, its power supply, and the controls for brilliance, focus, and shift. This article describes a circuit which is admirably suited to the above requirement, and which is designed for the 5BP1 or any of its equivalents. These are the tubes which have recently been released, and we are confident that a large number of our readers will welcome the information given here. This month's instalment forms Part I of an article which describes a complete 'scope circuit, built on the unit principle. Those who have no need for the second unit, which contains the time-base and amplifiers, need not go any further than this first instalment, and will not have the trouble of excising the parts they do not need from a complete circuit, since the tube unit described here is complete in itself.

THE CIRCUIT OF THE C.R.T. UNIT

This is shown in Fig. 1, which has all values marked on it. The top part of the circuit is the power supply proper, while the lower part is concerned with the deflecting plates only, and provides the X and Y shift voltages, as well as the deflecting plate leak resistances and the coupling condensers. The power supply is quite straightforward, and employs a series rectifier circuit, with the negative terminal above earth and the positive terminal grounded, as is usual in C.R.T. usage. The power transformer has two windings only; one of 2000v. R.M.S. rated at 5 ma., and the other of 2.5v. at 2 amps. for the rectifier filament. It is important to note that the filament winding as well as the H.T. winding must be insulated from the core of the transformer so as to stand a good deal more than the 2000v., but unless one is making one's own transformer this can easily be left to the discretion of the manufacturer. The 100k. resistor at the rectifier plate has the two-fold purpose of helping in the smoothing and dropping the voltage slightly so that approximately 200v. D.C. is found on the first filter condenser. If the dropping resistor is not used, it would be necessary to use a higher rated condenser instead of the 0.25 μf. 2000v. component specified, and this would be considerably more expensive.

Additional smoothing is provided by the second filter section consisting of a 250k. resistor and a 0.1 μf. 2000v. condenser. It might be argued that this second section is not strictly necessary, but in our opinion this is not so. Too often does one see a skimped design in which the final result is spoiled by 50 c/sec. hum causing partial blackout of the trace, particularly when the brilliance is turned down in order to get the finest possible trace. Thus, although a small amount of initial expense might be saved by omitting the second filter section, it was not considered worth while as against the superior performance gained by having a really well-filtered supply. The total resistance of the bleeder is approximately 1.75 megs., so that assuming a voltage of 2000 at the point indicated on the circuit, the bleed current will be 1.14 ma. This is somewhat higher than is found in many oscilloscope circuits, but again is good practice. If the bleed current is allowed to become too small, by having a high total bleed resistance, the current taken by the cathode ray tube is no longer negligible compared with the current through the bleeder. The net result is that the functions of the brilliance and focus controls become interdependent, and in bad cases, almost indistinguishable. If, as here, the power supply bleed current is many times the beam current of the C.R.T., then this effect is eliminated altogether, making for very easy adjustment under all conditions. Perhaps we should make clear at this point that although no photographs are shown of the original model, this circuit has been built in our laboratory, and is in daily use, so that readers need have no fear that the present design may not be a practical

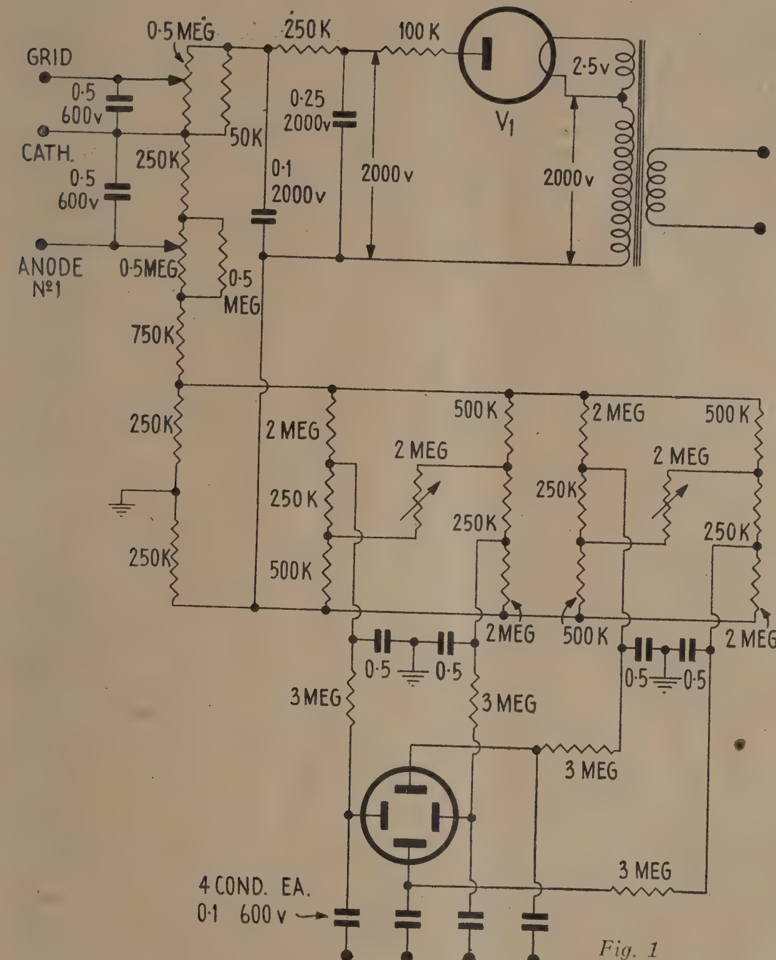


Fig. 1

one. Since the construction and lay-out of the unit can vary within wide limits, according to taste, as it were, it was not considered necessary to print photographs of the original.

In order to simplify the circuit diagram, the cathode ray tube has not been drawn, but the elements of the tube have been indicated on the diagram. The R.C.A. handbook shows all the anodes drawn in the manner usually used for grids, but this need not cause any uncertainty. However, in order to make quite sure that there will be no difficulty in following Fig. 1, it would perhaps be advisable to outline the connections of the tube. The socket is an eleven-pin magnal, with a keyway for ensuring that the tube cannot be plugged in incorrectly, and resembles an ordinary octal socket very closely, except for the greater number of pins. The pin numbering is done in the same way as for the octal, No. 1 being that one which is nearest to the keyway, on the left-hand side, when the socket is viewed from underneath. Nos. 1 and 11 are the heater pins, and the cathode is internally connected to pin No. 11. Thus, the point on Fig. 1 marked "Cath." is connected to pin No. 11. The point marked "Grid" on the circuit diagram is connected to pin No. 10, the grid pin of the tube. The point labelled "Anode No. 1" is connected to pin No. 4. The final anode, which does not appear on the diagram, comes out to pin No. 7, and is earthed to the chassis. The deflecting plates are connected to pins 3, 6, 8, and 9. The horizontal plates are Nos. 6 and 9, while the vertical ones are Nos. 3 and 8. The symbol we have used in our circuit diagram, at the bottom, for representing the deflecting plates, is self-explanatory, and should need no comment. However, for the uninitiated, it should perhaps be explained that this symbol, which is quite often used in C.R.T. diagrams, represents a cross-section through the tube. The deflecting plates therefore show as lines, and the top and bottom ones are called the *Vertical* plates, because when a voltage is impressed between them, the spot moves vertically up or down. Similarly, the left and right-hand plates are called the *Horizontal* plates, because a voltage placed on them will move the spot from left to right, or vice versa, horizontally. The terms "vertical" and "horizontal" therefore do *not* refer to the directions to which the plates are parallel, but to the directions in which they cause the spot to move. This is really much the most satisfactory way of designating them, since the direction of movement of the spot is the most important thing about the plates.

Readers will have noticed that the positive side of the H.T. supply is, in fact, not connected to chassis, but to chassis through a 250k. resistor, after the manner of the back-biasing resistor found in some receivers. In the latter, the voltage developed across the back-bias resistor is negative, and is used as a source of negative bias for the valves. Here, however, where the supply is the opposite way round from usual, the voltage across the back-bias resistor is positive. Its purpose is to provide a low-voltage positive supply for the shift control circuits, which will be described next.

SHIFT CIRCUITS

The circuits used for shifting the spot to any part of the screen may at first sight look complicated, but become less so when it is realized that the basic arrangement is simply that of Fig. 2, which shows how the shift voltages or one pair of plates are obtained. First of all, it should be pointed out that the arrangement illustrated, though a little more complex than other systems used, has the great advantage of providing balanced shift voltages. If, as in many 'scopes, one of each pair of plates is earthed, and signal and shift voltages are applied only to the remaining two plates, various forms of distortion are introduced into the picture, in particular, trapezium distortion, and deflection defocussing. Wherever possible, it is best to apply signals and shift voltages in push-pull to each pair of plates, as doing so results in a much better picture. Because of this, it was decided to use balanced shift circuits, and to bring out each deflecting plate to its own terminal. This enables balanced shift voltages to be used at all times, and ensures that each deflection axis can be fed with other balanced *or*

unbalanced signals, according to requirements. If an unbalanced signal is to be used, all that is necessary is to earth one of the input terminals. Since each input terminal has a blocking condenser between it and the deflection plate, doing so clearly has no effect on the D.C. arrangements, viz., the shift voltages.

By balanced shift voltages is meant that in order to control the position of the spot, each plate of a pair is given its own D.C. shift potential. Thus, if one of the Y plates is given a positive potential with respect to earth, its fellow must be given an equal negative potential. By this means, the average D.C. potential of the pair is kept zero, thereby preventing trapezium distortion and deflection defocussing. Now the requirements for the shift-voltage circuit for one pair of plates are first, that it shall provide balanced voltage at all times, and secondly that their polarity must be capable of being reversed. If this last condition were not obtainable, it would be possible to move the spot only on one side of the centre.

From the practical point of view, there is nothing difficult in devising a circuit that will fulfil these conditions. The first requirement is obviously a source of both positive and negative potential with respect to earth. It has already been explained how this is done in the present circuit. The lowest resistor in the bleeder chain, of 250k., has approximately — 285v. developed across it by the bleedcurrent, while the one below that, also of 250k., has developed across it + 285v. Most circuits that provide balanced, variable shift voltage employ ganged potentiometers as voltage dividers across the shift voltage supply. Unfortunately, ganged potentiometers are unobtainable in this country, so that other means have to be found. A well-known British radar receiver had a very ingenious circuit for overcoming this difficulty, and this has been used here. Basically it is shown in Fig. 2. There are two bleeds connected right across the positive and negative shift supply. These use values similar in ratio to those indicated, and are connected in opposite directions across the supply. The output voltages are taken from the junctions of the 2 meg. and 250k. resistors in each case, and the control consists of a 2 meg. potentiometer bridged across the junctions of the 250k. and 500k. resistors. To see how the system works, it is easiest to imagine the two extreme positions of the control potentiometer. One of these, namely where it is short-circuited, is realized in practice, while the other, where it is open-circuited is not, but this is not important to the argument. When the control is imagined as being open-circuited, the voltage at A is clearly quite close to that of the negative supply rail, while that of B is equally close to the voltage of the positive rail. Since the voltage dividers are identical, the voltages at A and B are equal and opposite with respect to earth, and this position corresponds to maximum shift in one direction. Now, when the control is short-circuited, we have the 500k. resistor in the right-hand divider connected right across the 2 meg. plus 250k. section of the left-hand divider, and vice versa. Also, from the symmetry of the circuit, it is apparent that the junction of the 500k. resistors with each other must be at earth potential; thus the point A is now at a positive potential with respect to earth, and the point B must be at an equal negative potential. The situation is therefore the reverse of that obtaining when the control is open-circuited. Also, somewhere intermediate between these two extremes, there must be a position of the control where A and B are at earth potential, and there is no shift voltage at all applied to the plates. Because the arrangement is quite symmetrical, the shift voltage must always be balanced. We have therefore realized our aim, and in the process have not used ganged controls. The circuit is therefore quite practical with standard components that are always available.

Because we have two sets of deflecting plates, we need two of the networks of Fig. 2, and these can be identified in the main circuit diagram. The only differences that can be observed between the complete shift circuit and that of Fig. 2 are the bypass condensers of 0.5 μf., and the isolating resistors of 3 megs. that are connected in each deflecting plate lead. The purpose of the isolating resistors is to see that the operation of the shift controls does not alter to any appreciable extent

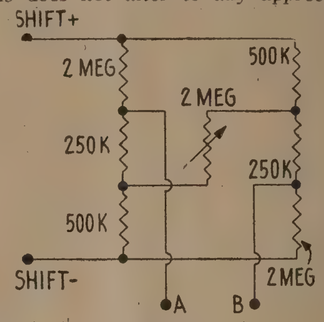


Fig. 2. Shift circuit for one pair of plates.

the impedance between the plates and earth. This impedance must always be as high as possible, especially where the C.R.T. is to be connected directly to the circuit under observation, and although the impedances in the shift circuits themselves are quite high, they vary considerably with the position of the controls. This variation is undesirable, particularly when it is realized that in one position of a control the impedance from A to earth falls as low as about 150k. The 0.5 μf. condensers are simply to ensure that the small residual hum of the power supply does not become directly applied to the deflecting plates, through the shift circuits. They also prevent completely any remaining variation in the deflecting plate impedances to earth.

OTHER POINTS IN CONNECTION WITH THE CIRCUIT

As extra precautions against hum affecting the tube operation, we have two 0.5 μf. 600v. condensers, one connected between grid and cathode of the tube, and the other between first anode and cathode. Their rating of 600v. is quite high enough, in view of the fact that the first one has only a little over 50v. across it, and the second not more than 600v. It should be borne in mind, however, that the whole condenser in each case is almost 2000v. below earth potential, so that care should be exercised in mounting them, to see that they are not in contact with the chassis, in case they break down, not between plates, but between one plate and earth. The use of a 0.5 meg. pot. for the grid bias, or brilliance control, is made possible by shunting it with a 50k. resistor, which limits the range of control, without making it necessary to raise the values of all other resistors in the chain, which is undesirable from considerations of lowering the total bleed current, as explained above. If a wire-wound potentiometer of 50k. were used, it would be sufficient in itself but carbon pots. are much less expensive, and with the circuit shown, will last indefinitely, in spite of the small D.C. passing through it. On no account should a 50k. carbon control be used, as it would have a very short life, and would soon become rough in action. Perhaps it should be mentioned that the control which

goes to the grid of the C.R.T. is the brilliance control, while the one feeding the No. 1 anode is the focus control. Thus, the whole unit has only the four controls: Brilliance, Focus, X Shift, and Y Shift.

CONSTRUCTION

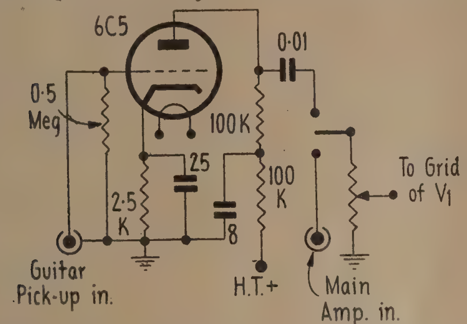
There is very little about a simple C.R.T. circuit like this that can cause any difficulty to a constructor other than the ever-present one of magnetic hum pick-up. This kind of hum has no connection with the hum which is caused by insufficient filtering of the supply voltages. In this circuit, filtering has been made very complete, with the result that this kind of hum is very unlikely, *as long as the circuit is strictly adhered to.* As far as magnetic hum is concerned, this is a matter completely outside the control of the designer of the circuit, and therefore is entirely up to the builder of the equipment to eliminate. The cause of it is the fundamental fact that electrons travelling down the cathode ray tube can be deflected not only by potentials applied to the plates, but also by any magnetic field in which the tube may find itself. There is only one type of component in the whole outfit that can produce a magnetic field, and therefore give rise to magnetic hum, and that is a transformer. Here we have two transformers, if a separate one is used for the C.R.T. filament, and one if a filament winding, not shown on Fig. 1, is put on the main power transformer for the C.R.T. If a separate filament transformer is used, this is not very likely to give trouble, and this can be placed quite close to the tube in any convenient position. The main offender is therefore the power transformer. It should be placed as far as possible from the C.R.T. so that its magnetic field at the tube will be as small as possible. It should also be turned until it has the least effect on the spot. The effect of this kind of hum will be readily recognized by the fact that the spot, when the brilliance is turned down low, and fine focus is made with the focus control, will be found not to be a spot at all, but an irregular ellipse or circle. The power transformer should then be turned round until the loop made by the spot is as small as possible. It will usually be found that the best position is with the core of the transformer parallel to the axis of the tube. When this has been done, the transformer mounting holes can be drilled, and the transformer permanently mounted. It is too much to expect that simple orientation of the transformer will remove the hum altogether, but after this has been done, one should try the effect of what hum is left on a picture thrown on the screen. If this should turn out to be negligible, then no more work need be done. If, as is most probable, the residual magnetic hum is still troublesome, then it is time to think about shielding the cathode ray tube. Since the hum is magnetic, the shield will have to be made of magnetic material. The best possible for the purpose is the alloy known as mu-metal, which has an extraordinarily high permeability. For this reason, it is possible to use a shield no thicker than 18 to 20 gauge, and get complete suppression of the hum. If poorer magnetic materials are used, the same effectiveness can be obtained only by increasing the thickness of the material. Now mu-metal is extremely hard to come by in this country, and it is very unlikely that the average constructor will be able to get any. This being the case, he will have to make do with what he can get, and perhaps the most readily available material is water or gas pipe, just wide enough in internal diameter to slip over the parallel part of the tube. Its main disadvantage is that of weight, and the fact that it will not be possible

(Continued on page 47.)

QUESTIONS and ANSWERS

CIRCUIT FOR A GUITAR AMPLIFIER

A. W. McD., Auckland, writes to ask if we can recommend an amplifier circuit suitable for working with a guitar pick-up of a well-known commercial type. The manufacturers of this pick-up advise us that its output voltage is somewhat lower than that of the average gramophone pick-up, but not so low as that of a low-level microphone. That is to say, an amplifier which will give full output from about 0.1 volt should have adequate sensitivity.



Circuit of the additional stage for using when the guitar pick-up is in use. Note the de-coupling in the plate circuit, and the switch for cutting the extra stage, when a pick-up is being used with the main amplifier.

Apart from this, the requirements for a guitar amplifier are very similar to those for any good audio amplifier, with one exception. Since a guitar does not produce any notes lower than about 100 c/sec., it is possible for its amplifier to dispense with extremely good low-frequency response. This enables it to be made a little more cheaply, because if the response is made to fall off rather rapidly after 100 c/sec., 50 c/sec. hum from heater-cathode leakage and similar causes is not so important as usual, nor is the response, so that the sizes of grid coupling condensers and cathode bypass condensers can be reduced somewhat.

Practically any of the small push-pull amplifier circuits that have appeared in our pages would be eminently suitable for guitar use, with perhaps the addition of an extra low-gain amplifying stage. The volume control could be placed at the input to the whole amplifier, or, if desired, after the extra first stage. For the sake of simplicity, the amplifier circuit we would recommend is the one which appeared in our first issue, April, 1946. This could be used without change, except for the addition of the pre-amplifier stage illustrated here. The whole arrangement would have more than enough gain for the purpose in hand, and keeping the volume control after the pre-amplifier stage would have the advantage of being less subject to noise than if it were at the input to the whole arrangement. The grid resistor of 0.5 meg. shown at the pre-amplifier stage is necessary in order to prevent this valve from working with an open grid circuit should the amplifier be turned on without the pick-up connected. The switching arrangement shown at the output of the pre-amplifier is optional, and would be useful if it is desired to use the amplifier for other purposes, when the extra stage is not needed. Otherwise it can be omitted. The decoupling resistor and bypass condenser should on no account be omitted, as the extra gain makes the whole amplifier more subject to motor-boating. The small coupling condenser also helps to prevent this fault. If the original chassis for the amplifier is used, there will be enough room for the extra valve socket in the left-hand front corner of the chassis.

DESIGN FOR A CAR-RADIO

L. H. T., Wellington, writes to ask us for the design of a really good car receiver. This is a subject upon which we do have some definite ideas, mostly connected with the aerial input circuit, since this is the most important section of any receiver which has to function well under the disadvantage of a small aerial. L. H. T. also brings up the question of the quality of reproduction from such a receiver, and states that though he would like to use a push-pull output stage, he has not enough room on an existing case and chassis to incorporate it. At the same time, he states that where improvement in performance is concerned, expense need not be considered an objection.

This is a very interesting letter, both to us, and, no doubt, to many readers who have had similar ideas to those of our correspondent. Unfortunately, however, his requirements are not altogether compatible, especially in view of the fact that he would like to make use of a number of valves and components that have already been purchased. However, we will try to give some idea of what is required in order to fulfil the specifications for a good car-radio as completely as possible.

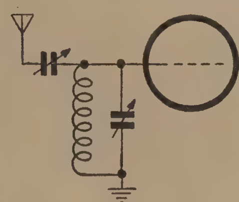


Fig. 1.

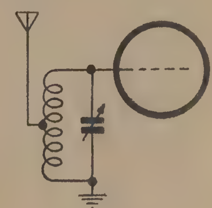


Fig. 2.

Two types of aerial coupling that are suitable for a car radio, but which are not used to any extent in ordinary receivers.

In a set of this kind, perhaps the most important thing, even more so than quality of reproduction, is that of good sensitivity, combined with a high signal-to-noise ratio. It is also the most difficult one to achieve, mostly because the pick-up from the small aerial to be found on a car does not provide anything like the signal to work on that a large outdoor aerial does. This means that the set's valve noise should be as small as possible, and that the aerial input arrangements should provide as much gain as possible. The ordinary kinds of aerial input coils used on broadcast sets do not in general provide very much gain themselves. For the home receiver, quite good characteristics can be achieved without having a very high-gain aerial coil, and in a set that has to work well on a large range of aerials, there are grave difficulties in designing high-gain aerial coils. In a car set, though, the situation is a little more favourable, for here the aerial's small size, and reasonably predictable characteristics, allow aerial coils to be used which would be quite unsatisfactory on a set which employed a large aerial. The question is one of de-tuning of the input circuit by the capacity of the aerial. If this is small, and does not vary over a very great range, it is possible to use direct capacitative coupling to the grid of the first valve in the receiver, or to use the simple, but effective scheme of tapping the aerial down the tuning coil for the first valve, either the R.F. stage or the mixer, if the former is not used.

The first of these schemes is illustrated in Fig. 1, and the second in Fig. 2. Neither of them are of much use when a variety of aerials have to be catered for, but are capable of much more than the usual degree of gain than can be got by the high-impedance type of aerial

coil. Of the two, the second is the better, because it can give better gain with aerials of high self-capacity, and most car aerials and their shielded leads suffer from quite high capacity for their small effective height. In any one instance, the tapped-coil aerial coupling can be made to give the best possible results, and one is not limited to the use of a commercially-designed coil. It is quite possible to achieve a gain, from aerial terminal to first grid, of 25 times.

Having realized a very good step-up in the aerial coil, the next most important thing is the valve noise, and in particular that of the first valve of the set. It should be possible with a high-gain aerial coil to dispense with a stage of tuned R.F. amplification, as long as the mixer used is not a noisy one, and this brings up the advisability or otherwise of using a triode mixer, such as the infinite impedance mixer. Unfortunately, if a triode mixer is used, without an R.F. stage, it is unlikely that the set's A.V.C. characteristic would be good enough, as another requirement for a car radio is that it should have an even better A.V.C. performance than most others. If we have no R.F. stage, and cannot put A.V.C. on the mixer, we are left with only the I.F. stage or stages to control, and since the most effective valve to control is one which comes earliest in the circuit, we would find our set with an A.V.C. performance that was inferior to the average instead of better. We must therefore give consideration to other things besides signal-to-noise ratio. Our own preference is to retain the triode mixer, and to use a stage of R.F. amplification as well. The latter will lessen the signal-to-noise ratio slightly, but will allow A.V.C. to be applied to the first valve in the set.

The next question is to decide on one or two I.F. stages. The triode mixer has not as much conversion gain as the more usual heptode or triode-hexode, so that it might seem necessary to have more gain than usual in the rest of the set, in order to counteract this sacrifice. Experience has shown that in domestic sets, the loss of gain is unimportant, as there is still "unusable" gain left. In a car set, however, we need more "unusable" gain, because even though it does not enable any weaker signals to be received, it can and does contribute to the effectiveness of the A.V.C. For this reason, it is desirable to compensate for the gain lost by incorporating a triode mixer. This can be done in one of two ways: either by using two low-gain I.F. stages, or having one high-gain stage. Since we have retained the R.F. stage, one high-gain I.F. stage should be plenty as far as gain is concerned, but it may be questioned whether this would give enough A.V.C. control. From the latter point of view, two stages would certainly be preferable, but there is another possibility that, though not often seen, should not be overlooked, namely, that of audio A.V.C. If the first audio stage is made either a triode or pentode, using for the job a variable-mu pentode, with the appropriate connections, the effectiveness of the A.V.C. can be much greater than is ordinarily the case. In addition, this can be done with only very slight increase to the overall distortion of the receiver.

Thus, we arrive at the following valve line-up as far as the first audio stage:—

R.F. amplifier, 6K7, 6SK7, EF39, EF41, or 6BA6.
Oscillator-mixer, 6SN7.
I.F. amplifier, 6BA6.

Second detector and A.V.C. rectifier, 6H6 or EB34.
First audio (A.V.C. applied), 6K7, 6SK7, EF39, or EF41.

We now come to the question of what sort of audio amplifier should be incorporated in a car-radio. In the first place, it is very debatable whether any attempt at realizing high-quality reproduction is justified. This may seem an odd statement to make until some of the factors involved are given due consideration. It goes without saying, of course, that here, as always, distortion should be kept to an economic minimum, but the above uncertainty comes about through the restrictions placed on the set by its location, namely in a car, where only a small loud-speaker can be used, and where listening conditions themselves do not allow fidelity reproduction to be obtained. Included in the unfavourable listening conditions are the small internal volume of the car body, and the presence of extraneous noises, such as engine noise, and noise from passing vehicles. By the latter we do not mean electrical noise, which can be assumed to be satisfactorily suppressed. The small size of the inside of the car, and the existence of external noise both militate against the provision of a good low-frequency response. The former tends to prevent such from being obtained in any case, while the latter reduces the intelligibility if an extended low response is attempted. Also, in a car, it is seldom possible to place the speaker in a good position from the listener's point of view. For example, it is often found under the dash, aimed somewhere about the passengers' feet! This, too, makes the frequency response for the best-sounding results quite different from that of an ordinary domestic set.

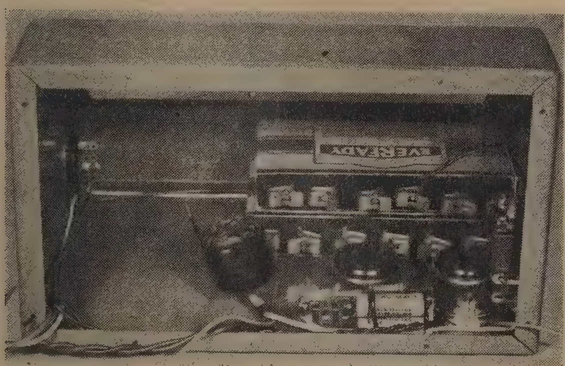
It is thus desirable to have an audio amplifier in which the low-frequency response is somewhat restricted, in order to avoid overloading the speaker, and in which the high-frequency response is good, but not over-accentuated. Both these things can be looked after in the design of the audio circuits, the former by purposely making the grid-coupling condensers a little smaller than usual, and the latter by providing some kind of pre-set control of the highs.

Since a small speaker must be used, and these are seldom as sensitive as, say, an eight-inch unit, it is necessary to have ample audio power output. A good three to four watts should be sufficient, so that the number and kind of output tubes can be determined by the voltage and current ratings of the power supply it is intended to use. For instance, if a full 250v. is available, at a current of 60 to 80 ma., for the whole set, a single 6V6 should be ample, particularly if it is provided with negative feedback, to ensure that the distortion is low even near full output. If the 6K3 or EF39 gain-controlled first audio stage is pentode connected, only the output stage will be needed, making the set six valves in all. If a great deal of feedback is required, it would be better to use an extra audio stage, such as a 6C5 or 6J5, with the feedback taken from the plate of the output valve to the cathode of the 6C5. In this case the gain-controlled stage should be triode-connected, as the high gain of the pentode circuit will not be required. The set would then have seven valves, and should be capable of very fine results indeed. We hope these remarks will be of assistance to many readers who have wanted information on the design of a car set. Many, we know, will be able to proceed from what we have given and complete the detailed design themselves.

A Mutual Conductance Valve-Tester Using A New Principle of Measurement

PART 2

The transformer for supplying heater current for the valve to be tested is placed on the second chassis. It will be seen that no particular heater voltages have been specified, as the range of voltages needed will depend on individual requirements. For many users a simple 6.3v. transformer will be sufficient, or, at most, one with 6.3 and 2.5v. S_5 is the heater or filament voltage selector switch. The heater banana sockets are floating with respect to the cathode. The left-hand winding is for supplying directly heated tubes. Suppose that we want to be able to test filament type valves requiring 2.5, 4, and 6.3v. supplies. The filament pins would then be connected to the two banana sockets labelled A.C.Fil. The 2.5, 4, and 6.3v. positions on both sections of S_5 correspond, so that there is no need for a separate switch to take care of the directly heated tubes. In all other positions of S_5, when S_{5a} is supplying heater voltages higher than 6.3v., the shorting of the remaining contacts of S_{5b} ensures that the junction point of the filament centre-tapped resistor, R_5R_6, is at earth potential for the 50-cycle filament voltage. Otherwise, when cathode-type tubes were being tested, there would be about 3v. at 50 c/sec. impressed on the cathode of the valve, and this would tend to be picked up by the indicator circuit, destroying the indication and spoiling the measurement.



Back view of the inside of the main unit. The bias batteries, and the sockets for V_1, V_2, and V_3, can be seen. At the left, towards the front, is the connector socket, not completely wired as the photo was taken.

The question of hum is therefore an important one, as any hum, from whatever source, that finds its way on to the output terminal of the tube, will be read as signal by the indicating circuit and destroy the accuracy of the measurement. This is the real reason for using a 1000 c/sec. oscillator as the signal source. With this, it has been possible to design the indicator circuit so that its response to 1000 c/sec. is within 1 db. of its maximum gain, while its response to 50 c/sec. is cut to less than 30 db. below this figure. It is unlikely, therefore, that hum can cause trouble. This low frequency cut is done by making all the coupling condensers very small, a point that the reader may have wondered about.

THE TESTING OF PENTODES

It is possible to arrange a pentode as a cathode follower and to measure its mutual conductance in exactly the same way as has been described for triodes. All that is necessary is to drop the voltage to the screen in the usual way, and then bypass the screen to the **cathode** of the valve, and not to earth. With small voltage amplifier pentodes, this can be done quite easily, and since the valve manuals quote the gm of these tubes when connected as pentodes, it is necessary to test them in this way. In testing a pentode, it is the screen voltage and grid bias that control the gm, rather than the plate voltage. Thus, the same situation holds as for triodes—namely, that the screen voltage in itself is not critical, as long as the bias **and** screen voltage combined cause the valve to draw rated plate current. Thus, the exact values of the screen dropping resistors are not critical, and as long as one of them is used, by manipulating S_4, so that the valve really operates as a pentode, having its screen bypassed to cathode, the bias control will enable the correct plate current to be obtained. In testing a pentode, the suppressor can be connected to earth, so that the banana socket labelled Supp. has been connected permanently to earth and causes no complications. When triodes are being tested, the screen voltage switch can be in any position. The switch allows a choice of three screen dropping resistors, and has a fourth position in which the screen is connected directly to the plate. This enables the pentode to be tested as a triode, if desired. It is also necessary for testing power pentodes and beam tetrodes. These have to be tested as triodes, with the present set-up, because the valve manuals usually quote the gm for these tubes with equal plate and screen voltages. In order to work them as pentodes in this instrument, it would be necessary to provide a high H.T. voltage and to drop both plate and screen voltages separately from it. This is the only way in which it would be possible to bypass the screens of these tubes to cathode and therefore to make them operate properly as pentodes. However, it was not thought that the extra complication involved was worth the trouble, for, luckily, the mutual conductance of these valves when connected as pentodes is only slightly different from their gm when triode-connected. Thus, only a small error is involved in testing them as triodes. In any case, many of them have their triode gm quoted in the valve manuals. If the error is important, allowance may be made by means of a simple formula which relates the two mutual conductances to the plate and screen currents of the valve.

The only feature of the circuit that has not been touched upon is the inclusion of a 1.4v. cell for use when testing 1.4v. valves. This is not strictly necessary, but is a simplification where builders wish to test only 6.3v. and 1.4v. valves, as it saves the necessity for a 1.4v. winding on the filament transformer. In testing a 1.4v. filament valve, one filament lead is taken to the cathode terminal and the other is taken to the terminal labelled Batt. Fil. The 1.4v.

cell remains attached to the cathode terminal at all times, as it has no effect on the operation of the circuit.

CONSTRUCTION

The photographs and chassis diagram give a good idea of how the tester may be built as a very compact unit. The second unit has not been illustrated, as this can be made to suit individual requirements. Apart from the paralleling of the test socket leads, there is very little circuitry attached to this part of the tester. It can be made as small or as large as necessary, having regard only to accommodating the necessary test sockets and the filament transformer and switches.

The main unit is the first one, containing the oscillator, indicator circuit, meter, etc. This is illustrated in the photographs. It is a simple sloping panel unit, many of the components being mounted directly on the panel. The photograph shows both back and front views of the panel, taken while the unit was under construction. By making it in this way, and dispensing with a chassis, it was found possible to get the parts into a smaller space than would otherwise have been practicable. Looking at the panel from the front, the controls are as follows: The shaft on a level with the centre of the meter is the calibrated cathode load resistor. The row underneath, reading from left to right, comprises the bias voltage control, R_{15}, the Cal./Test switch, S_2, and the oscillator output control, R_5. Underneath is the On/Off switch, S_1. The plate volts, screen volts, and filament volts selector switch are on the second chassis. Thus it can be seen that we have kept the controls on the measuring unit to those which are actually concerned in taking a measurement, while all the switches concerned with the prior setting-up of the test circuit are located on the test-socket unit. This makes for convenience in operation, especially where a batch of tubes of the same type is being tested, since once the setting-up is completed, all operations are performed using the main unit.

The photograph of the inside of the cabinet shows how V_1 and V_2 are mounted, on a base-board type of socket. The small terminal strips carry all resistors in the oscillator circuit, with the exception of R_5, and all the indicator circuits' small parts. The two 9v. C batteries can be seen behind the valve sockets. The only parts missing from this photograph are the power supply components, which go in the space at the left of the photograph. There is enough room for a power transformer of the 80 ma. flat-mounting type, standing on its side with the open side (normally the bottom) facing to the right. The use of this type of transformer removes the need for providing a terminal strip for the leads. The circuit is wired directly to the transformer lugs. The 6X5 rectifier can be mounted with a socket similar to those used for V_1 and V_2, and so placed on the left-hand side of the cabinet as to bring the valve directly above the power transformer. In the photograph, at the left, the output connector socket can be seen, mounted low down on the side of the cabinet. A suggestion for the second unit is to give it the same cross-section as the one illustrated and to mount a male connector plug in a corresponding position so that the two units can be butted against each other, and the connections made, without the use of a cord.

SETTING UP FOR USE

Once the main unit has been constructed and the second unit has been added, all that has to be done is to calibrate R_{18} and draw a suitable dial scale for it. The calibration can be done by connecting an ohm-meter across R_{17} and R_{18} by plugging the leads in to the phone jack. Then the calibration marks are made on a temporary scale (or in pencil on the permanent one) by adjusting R_{18} to the values of resistance indicated in the following table. If R_{17} is exactly 50 ohms, the minimmum-resistance end of R_{18} can be labelled 20 ma./v. Now, to mark in 15 ma./v., R_{18} is adjusted to a total resistance for $R_{17} + R_{18}$, of 66.6 ohms. The position of the pointer is then marked with the figure 15. The procedure is repeated for each calibration mark that is desired. The high end of the scale is fairly cramped, and it can be left to the discretion of the constructor how many points are marked in between 10 and 20 ma./v., for example. Below 10 ma./v. it should not be difficult to mark in every one ma./v., as it will be seen that the scale gets progressively more open towards the low-reading end. The table is as follows. Any points that are not included but which it is desired to mark in can be calculated from the relation

$$R = \frac{1000}{gm}$$

where gm is the required point in ma./v., and R is the associated resistance reading.

CALIBRATION TABLE FOR $R_{18} = 1000$ OHMS

Note.—The value given is for $R_{18} + R_{17}$, so that the values must be measured across both resistors, not just across R_{18}.

Reading. Ma./v.	Resistance. Ohms.
20	50.0
15	66.6
10	100.0
9	111.1
8	125.0
7	143.0
6	166.6
5	200.0
4.5	222.5
4	250.0
3.5	286.0
3.0	333.3
2.5	400.0
2.0	500.0
1.9	537.0
1.8	556.0
1.7	589.0
1.6	625.0
1.5	666.6
1.4	715.0
1.3	780.0
1.2	835.0
1.1	910.0
1.0	1000.0

When the scale has been calibrated in this way, the instrument is ready for use. To test a valve, the complete procedure is as follows:—

(1) The tester is turned on and the Cal./Test switch is set to "Cal."

(2) The valve to be tested is plugged into the socket and the wander-leads or selector switches are set to the correct positions by reference to the under-socket connection diagram of the valve.

(3) The plate voltage selector switch is set to "Max." for A.C. valves, or "45v." for battery valves.

(4) If the valve is a voltage pentode, the screen voltage switch is set to one of the dropping-resistor positions. If a power pentode, this switch is set so as to connect the screen to H.T.

(5) The noise-test switch is closed.

(6) The oscillator output control is set so that the magic eye is just closed.

(7) The Cal./Test switch is thrown to "Test."

(8) The grid bias is adjusted until the required plate current is indicated on the meter.

(9) The calibrated cathode resistor is adjusted until the eye is just closed and the mutual conductance is read from the dial.

PRECAUTIONS TO BE TAKEN

When triodes or power pentodes are being tested, it is essential that the bias control be set to give minimum plate current **before** the Cal./Test switch is thrown to "Test," and plate voltage is applied to the tube. If this is not done, the plate current on switching on may be much too high either for the good of the valve or the milliameter. A practice should therefore be made **always** to set the bias to its maximum negative position after a valve has been tested and to bring the bias voltage down after the next valve has been set up in the tester. The dropping resistor, R_{19}, gives protection against too little bias on large tubes, as it automatically reduces the plate voltage when heavy current is drawn. It also enables a bias battery of 18v. to cope with a valve such as the 2A3, since it drops the plate voltage low enough for only 18v. to be effective in setting the plate current to 60 milliamps.

COMPENSATION FOR ERRORS WHERE AN EXACT ANSWER IS REQUIRED

In Part 1 of this article, it was mentioned that there is an approximation involved in assuming that the mutual conductance is equal to $1/R_c$. The actual figure that should be used is given by the formula

$$g_m = 1/R_c - 1/R_p$$

where R_c is the cathode resistor used to realize the condition that the output voltage is 0.5 times the input voltage, and R_p is the plate resistance of the valve under test. With pentodes, and with triodes whose plate resistance is high, the error involved in ignoring the second term in the above equation is negligible, and amounts to only a small fraction of a milliamp per volt. With triodes whose plate resistance is only a few thousand ohms, however, the error can become quite large. Luckily, however, it is easily corrected by means of a very slight bit of arithmetic. This is to work out the value of $1000/R_p$, where R_p is expressed in ohms, and *subtract* the figure so obtained from the answer given by the tester. Thus, a valve whose plate resistance is 1000 ohms, and whose actual g_m is 5 ma/v., would give a reading on the tester of 6 ma/v. The correct answer would be obtained by subtracting $1000/1000 = 1$ ma/v. from the measured figure of 6 ma/v. It is easy to see at a glance the order of the correction required to make the reading accurate for any triode if its plate resistance is looked up in the valve book. For example, a valve with a normal plate resistance of 10,000 ohms would read high by only $1000/10{,}000 = 0.1$ ma/v. On the other hand, a 2A3, with a plate resistance of only 800 ohms would read high by $1000/800 = 1.25$ ma/v. Thus, the correction is worth making only in the case of low-impedance triodes, and when means are available to read the tester to much greater accuracy than can be got from the direct-reading scale.

HOW VERY EXACT READINGS MAY BE OBTAINED

Supposing that the accuracy required from the tests is much greater than that needed for routine purposes, as, for example, when a piece of original work requires a very accurate knowledge of the mutual conductance of particular valves. One of the beauties of this new method is that its accuracy can be made as high as necessary. In this way it resembles bridge methods, which can be used for rough checks, or for super-accuracy, according to the need, and the equipment available.

Only two things need to be known with great accuracy if the resultant accuracy of the measurement is also to be high. They are, first, that the divider which provides the reference signal for the calibration of the magic eye must give an output exactly equal to one-half the input voltage, and secondly that the value of the cathode resistor shall be accurately known after the adjustment has taken place. Since the frequency of the signal is only 1000 c/sec., and carbon resistors have negligible reactance at audio frequencies, it should be sufficient to choose the resistors for equality on a good Wheatstone bridge, making the measurement with D.C. This has to be done only once, in the construction of the equipment. The variable resistor that for comparatively rough measurements is calibrated, can for accurate readings have its terminals brought out to the front panel. Then, after the resistor has been adjusted, as described above, its value can be accurately measured with a 1000 c/sec. bridge. If the voltage divider has been made exactly, the overall accuracy of measurement will be comparable with that of the bridge used to measure the value of the cathode resistor. In this case, of course, the correction for plate resistance will have to be made, except in the case of pentodes, where it will still be negligibly small.

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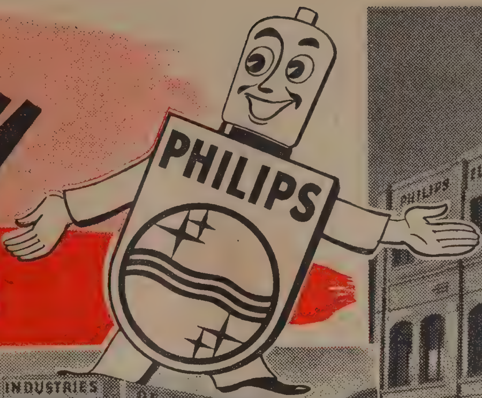

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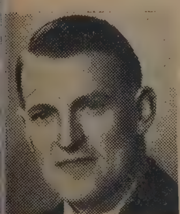

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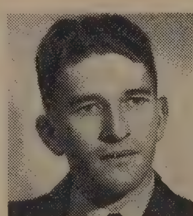

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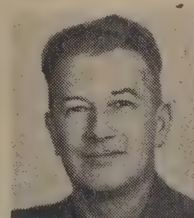

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A Radio Tuner Employing Multi-Point Selectivity for High-Fidelity Reproduction

Part 2

The first instalment of this article dealt with the principle employed in the tuner, and this one, which describes the complete tuner circuit, starts with an appraisal of the merits of the method used in it for obtaining variable selectivity.

(2) Flexibility and Range of Operation:

In this respect, the present scheme is definitely superior to all others except the variable mutual-inductance one. Any number of selectivity positions may be provided. Better than this, the components associated with any one position are quite independent of all other components, with the sole exception of C_3, which has to be chosen first, as it determines the greatest bandwidth that is to be provided. Once this has been decided, any number of narrower positions can be provided, if desired, so that it is possible to approximate a continuously variable system.

The range of operation is superior to the tertiary system by a great deal. With a tertiary winding, it is not possible to keep the Q of the windings particularly high, owing to the fact that the switching takes place in the inductive branch of the circuit. For this reason, it is not desirable to reduce the Q of the second I.F. transformer sufficiently just to fill up the valley in the double-peaked response curve of the over-coupled transformer, since doing so reduces the selectivity of the skirt of the response curve to the extent that the adjacent-channel selectivity is no longer good enough. Thus, with the tertiary system, the degree of over-coupling that can be used in the first transformer is somewhat limited. With the bottom-capacity-coupled system used here, however, the Q of the coils can be as high as it can be made, because the losses introduced by the coupling system are very slight as long as good quality silvered mica condensers are used. It now becomes possible to shunt the windings of the final I.F. transformer without losing very much skirt selectivity. The adjacent channel selectivity of the I.F. amplifier as a whole is therefore comparable to that of any ordinary I.F. stage, and any desired degree of over-coupling can be used in the first "transformer," with the knowledge that the response within the pass band is sufficiently flat, however wide the pass band may be.

(3) Quality of Results Obtained:

If properly designed, the present system is capable of almost as wide a pass band, with consequently excellent frequency response, as can be desired. An overall audio frequency response for the complete tuner can easily be made flat within 2 db. up to 10,000 kc/sec. It is because such a wide response is not always usable that narrower selectivity positions are desirable. In fact, with the present overcrowding of the broadcast band, a tuner with a response as wide as this can often produce a 10 kc/sec. whistle, this being the heterodyne between adjacent R.F. carriers. For this reason it is a good plan to compromise somewhat and make the maximum bandwidth about 15 kc/sec., giving an audio response out to 7500 kc/sec., and yet allowing the skirt selectivity of the tuner to suppress the 10 kc/sec. whistle considerably. However, in any locality where the local station or stations are very strong—for example, in main centres—it is not necessary to compromise in this way, and the maximum possible bandwidth can be used. If heterodyne trouble is experienced, it is possible to eliminate it by inserting in the audio amplifier a sharply-tuned filter for 10 kc/sec.

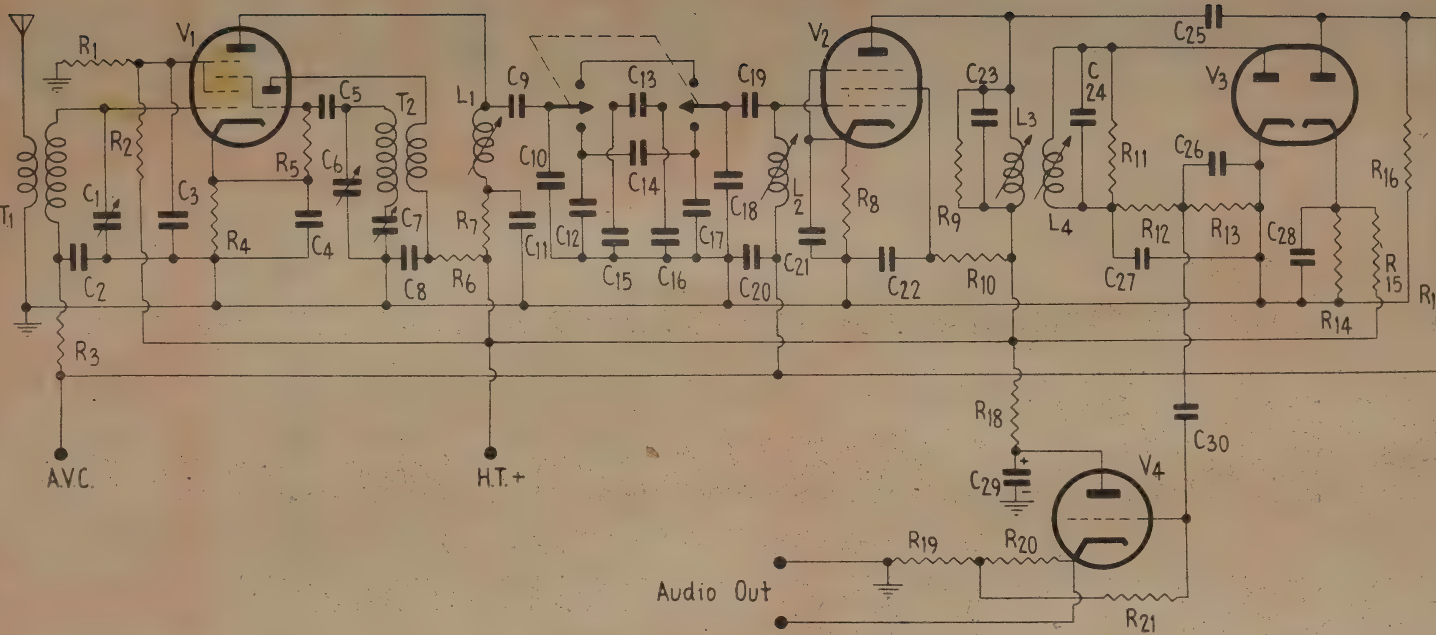
The outstanding advantage of the bottom-capacity-coupled "transformer" is that, with it, the expansion of the I.F. bandwidth can be made to take place quite symmetrically about the I.F. centre. Thus, the uncertainty of knowing where to tune the receiver when switched to the wider positions is completely avoided by tuning in the signal with the selectivity switch at "narrow" and then turning it to "broad," or to an intermediate position. Any successful system must allow this to be done, but here, as with mutual-inductive coupling, the objective is attained automatically as long as the values of the condensers are within the recommended tolerance.

THE COMPLETE TUNER CIRCUIT

We have spent a good deal of time and space enlarging upon the method we have used to get the needed variation of selectivity, because the circuit for doing this is the most important single feature of the tuner. In spite of this, there are a number of other features in the design which, if not quite so spectacular, are just as important to the fine overall performance that the tuner achieves. It will be noted, by reference to the complete circuit diagram, that the second I.F. transformer has both windings shunted by resistors. The purpose of these has already been indicated. It is to reduce the Q of the windings to the point where the single-peaked response of this transformer just fills the gap between the peaks of the over-coupled pair of circuits between the mixer plate and the I.F. grid. If the Q is not reduced in this way, the overall response exhibits **three** peaks—one on the I.F. centre and the others spaced on either side of it, with the centre one a good deal higher than the other two. The result is a pronounced falling-off in audio response at high audio frequencies, in spite of the wide band under the selectivity curve. On the other hand, if the Q of the second I.F. transformer's winding is too low, there will still be a dip in the overall response curve, though not so serious a one as is exhibited by the first pair of circuits alone. Part of the loading on the secondary is provided by the load resistor of the detector diode. For this reason, the loading resistor across the secondary has a higher value than the one across the primary.

NO R.F. STAGE

It may surprise some to see that the tuner does not employ a stage of R.F. amplification. Such a stage was purposely omitted, because of the extra difficulty it would introduce in ensuring that the selectivity of the tuner is governed as far as is possible by that of the I.F. amplifier. Any selectivity at signal frequency is added to that of the I.F. amplifier, and when an R.F. stage is used there are two tuned circuits at signal frequency. In order that their effect might be small, it would be necessary



COMPONENT LIST

V_1, ECH41.
V_2, 6BA6.
V_3, 6H6.
V_4, 6J5.
T_1, Aerial Coil.
T_2, Osc. Coil.
L_1, L_2, Midget I.F. Coils, permeability tuned, and designed for a fixed tuning capacity of 100 $\mu\mu$f.
L_3, L_4, C_{23}, C_{24}, I.F. Transformer, permeability tuned.
R_1, R_{12}, 50k.
R_2, R_6, 40k.
R_3, R_{19}, 100k.
R_4, 200ω.
R_5, 25k.
R_7, 2k.
R_8, 50ω (see text).
R_9, R_{11}, R_{15}, 250k.
R_{10}, 35k.
R_{13}, R_{21}, 500k.
R_{14}, 10k.
R_{16}, R_{17}, 1 meg.
R_{18}, 50k.
R_{20}, 1500ω.
C_1, C_6, 2-gang tuning condenser.
C_2, C_{11}, C_{20}, C_{30}, 0.05 μf.
C_3, C_4, C_{21}, C_{22}, C_{28}, 0.1 μf.
C_5, C_{25}, 50 $\mu\mu$f.
C_7, 600 $\mu\mu$f. padder.
C_8, 0.01 μf.
C_{26}, C_{27}, 100 $\mu\mu$f.
C_{29}, 8μf. 450v. Electro.

Condensers in I.F. Coupling Network (N.B.—5% or better (see text):

C_9, C_{19}, 100 $\mu\mu$f.
C_{10}, C_{18}, 0.001 μf.
C_{12}, C_{17}, 750 $\mu\mu$f.
C_{15}, C_{16}, 200 $\mu\mu$f.
C_{13}, 0.0024 μf.
C_{14}, 300 $\mu\mu$f.

either to reduce their Q or else to use complicated aerial and inter-stage coupling systems in order to give them a wide pass band. In the first case, the major advantage of the R.F. stage at broadcast frequencies—namely, the provision of better image projection—would largely be lost, while the second idea is exceedingly difficult to put into practice. In addition to all this, there is always the possibility that regeneration may occur in the R.F. stage to a sufficient extent to nullify completely the variable selectivity of the I.F. channel. The sensitivity increase consequent upon the use of the R.F. stage is quite unnecessary; this will be all the better appreciated when it is stated that the tube line-up shown, in conjunction with an audio amplifier of normal power sensitivity, gave a measured sensitivity of 4 microvolts for 50 milliwatts output! On balance, then, it was decided to omit the R.F. stage, more especially since the design was to be presented here for the benefit of amateur constructors, who would certainly not wish to have their time and trouble wasted through the occurrence of regeneration that is hard to eliminate.

HIGH-GAIN I.F. AMPLIFIER USED

This tuner is intended not only to fulfil the necessary conditions for high-fidelity local station listening, but also to qualify as a reasonably sensitive and selective unit for distant reception. Because of this, and bearing in mind the fact that the I.F. transformer which forms the tuned load impedance for the I.F. amplifier valve has a lower Q, and therefore a lower dynamic impedance than usual, thus tending to give the I.F. stage a smaller gain than usual, it was decided to use a high-slope variable-mu pentode as the I.F. amplifier. The choice fell upon the miniature 6BA6, which has more than twice the mutual conductance of the more usual R.F. pentodes. Its small size is also an advantage. It also has the virtue of availability in these hard times!

SECOND DETECTOR, A.V.C. RECTIFIER, AND OUTPUT VALVE

The circuit used in this part of the circuit is a well-tried one, which has often appeared in these pages. It is used here on account of its admirable suitability to a high-quality circuit, both from points of view of low detector distortion and effective A.V.C. action. The distortion aspect is a very serious one in a device such as this where we are attempting to increase the frequency range handled by the whole reproducing system. The more the high-frequency response of a system is extended, the greater is the necessity to see that the distortion is kept to a minimum. In view of the very heavy distortion that the diode detector can produce if not properly designed, this is in some ways the most critical part of the circuit. As ever, only much more so than usual, the

chief source of distortion from the detector is inequality of the A.C. and D.C. loads on the diode. Two things can be done about this. First, we can dissociate the loading of the A.V.C. rectifier from the detector circuit by shunt-feeding the former directly from the plate of the I.F. amplifier. This has the added advantage of providing a greater A.V.C. control voltage. The other offender in normal circuits is the loading imposed on the detector diode load by the grid resistor of the first audio amplifier valve. The more usual way of minimizing this (without entirely eliminating it) is to make the diode load the volume control potentiometer. This results in a low setting of the control for strong signals, if, as is ordinarily the case, the audio amplifier has considerable voltage gain. The grid resistor of the first audio stage is therefore placed across only a fraction of the diode load resistor when strong local stations are being received. The detector is then able to handle high modulation percentages without introducing appreciable distortion. Another course that is equally effective, and which obviates the necessity for making the volume control into the diode load, is to use a cathode-follower as the first audio stage. The input impedance of the cathode follower output stage shown here is in the region of 20 megohms, which is 40 times the value of the load resistor of $\frac{1}{2}$ meg. It is not always economic to do this, however, especially in a set that has to be built down to a price, but here the advantages outweigh by far the cost of the extra valve and a few components. The cathode follower, as well as assisting in improving the quality of the detector, contributes virtually no distortion of its own, and simultaneously provides an output terminal of about 400 ohms impedance. Since the tuner will no doubt be used most often to feed a separate amplifier, this is very advantageous, as the low output impedance makes it possible to separate the tuner and amplifier by any desired distance. The output lead can be shielded without introducing high-note loss, and, in any event, shielding becomes unimportant, as hum pick-up will be very slight.

The cathode follower is sometimes criticized as a low-level output coupling device on the score that the comparatively high D.C. potential between heater and cathode introduces hum itself. Where very low signal levels are concerned, this objection is no doubt valid, but in this case it will be noted that the tuner incorporates no volume control. Because of this, the full output of the detector is passed to the cathode follower at all times. The audio level is therefore in the region of two to three volts, which is more than enough to swamp any hum that arises in the cathode follower. This was proved when our prototype tuner was built and fed to an amplifier which has so little hum as to be inaudible, even with the gain control full on. The test consisted in removing the I.F. amplifier tube, so as to remove all other types of noise, and to turn the amplifier gain control wide open. Even under these conditions the hum was barely audible from a distance of six feet or so.

SOME CONSTRUCTIONAL POINTERS

Readers will no doubt wish to know whether this somewhat unusual circuit has any peculiarities of the kind which necessitate special care in its construction. The answer, we are glad to be able to say, is in the negative, as long as it is remembered that extra good stability is required and that the I.F. amplifier is a high-gain one. For example, both the ECH41 mixer and the 6BA6 I.F. stage need shielding. In addition, a baffle shield across the 6BA6

socket is necessary. A point in connection with stability that is not usually met with is the bypassing of the 6BA6 cathode resistor. It will be noted that this resistor is quite small, because of the fact that the 6BA6 can quite easily do without any minimum bias at all and because the extra gain obtained by leaving it unbiased except for A.V.C. is not needed. A very small cathode resistor like this needs a very large bypass condenser, so that if a tendency to instability is found, matters may be improved, and sometimes cured altogether by removing both bias resistor and bypass condenser, earthing the valve's cathode directly!

The coils in the interstage coupling systems are midget shielded single units, permeability tuned, and made to plug into small four-pin sockets. The first, in the plate circuit of the mixer, should be mounted as close to the mixer socket as possible, to ensure a short plate lead for this valve. The selectivity switch should be a wafer type, with two single-pole three-position units on a single bank. It should be mounted right beside L_1, with the shaft making a right-angle with a line drawn through L_1 and L_2, so that the wafer lies between the two coils. It is then possible to make short leads between the coils and the 100 $\mu\mu$f. condensers that are directly connected to them. The condensers making up the pi-networks are then connected right at the switch contacts. The best physical arrangement for the circuit is one which exactly follows the progress of the circuit diagram and the part that has already been described conforms to this scheme. The lay-out of the oscillator-mixer components is not critical, and can take any convenient form. The straight-line type of lay-out for the I.F. and second detector portion of the circuit will automatically give short leads where they are needed, and as long as an under-chassis shield is placed across the 6BA6 socket, as suggested, and the ECH41 and 6BA6 valves themselves are enclosed in shield cans, there should be no trouble about attaining complete stability. The cathode follower should be placed as close to the 6H6 second detector as possible, and the lead to its grid made very short indeed. The same high input impedance that makes it so useful also makes it particularly susceptible to hum in its grid circuit, so that if the tuner is built as part of a complete set, with the power supply on the same chassis, care should be taken to keep it well away from the power transformer and smoothing chokes, as well as to keep the input lead short. It does not matter at all where the output lead is taken because of the low impedance at this point.

VALUES OF CONDENSERS IN THE SELECTIVITY NETWORK

As mentioned above, it is necessary for all condensers associated with the variable selectivity to be correct in value within 5 per cent. The values that are required are such that only the minimum of parallelling, in order to realize specified values, is necessary. It is probable that not all firms who supply components will be able to provide condensers within the specified tolerance, in which case builders will have to see if they cannot find some firm which has an accurate bridge. It might be possible, for a small fee, to get them to sort out mica and/or silvered mica condensers of the right values, or even to allow the purchaser to do so himself with the aid of their bridge. The most economical way of making up the required values is as follows:—

C_{12}, C_{17}, 500 $\mu\mu$f. plus 250 $\mu\mu$f. C_{14}, three 100 $\mu\mu$f.
C_{15}, C_{16}, no parallelling. C_{13}, 0.002 μf. plus two 200 $\mu\mu$f.

ALIGNMENT

As stated above, there is nothing at all unusual about the alignment of this tuner. All that has to be done is to make sure that the switch is in the narrow position, which in the circuit diagram is the one where C_{12}, C_{14}, and C_{17} are in circuit, and align the I.F. and signal circuits in exactly the normal manner, as though the variable selectivity feature were absent. The only point we would stress is that the I.F. alignment should be carried out with somewhat more than the usual care, to see that every adjustment is *exactly* "on the nose" after the job has been completed. By this, we mean to say that if there is the slightest hand capacity effect on approaching and removing the alignment tool, this should be allowed for by adjusting each slug so that maximum reading on the output meter is obtained *after the tool has been removed from the set.* This makes the adjustment a little tedious if there is any hand-capacity effect, but ensures that the pass band on the wide and intermediate positions will expand in a symmetrical way about the centre frequency. When alignment is carried out carefully in this way, the expansion of the pass band will be quite symmetrical. If it is not, then the only possible reason for it is that the condensers have not been chosen with sufficient accuracy. In operating the tuner, a marked increase in high-frequency response will be apparent in the wider positions, and when recorded music is being played, there will be a noticeable increase in record scratch. The important thing about this is that *on no account should the tuning be adjusted after switching to the broad selectivity position.* There may be a tendency to do so, because the user tends to get the impression that the extra high-frequency response is due to improper

(Continued on page 48)

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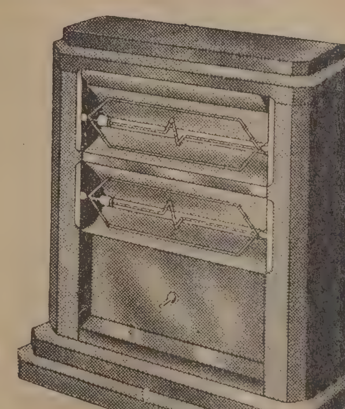

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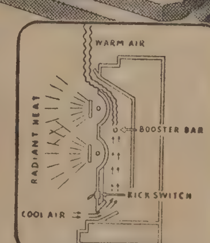

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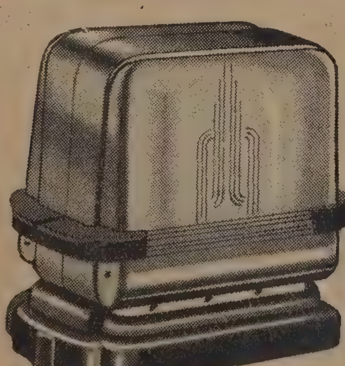

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AUDIO EQUIPMENT AND DESIGN:

Dynamic noise suppressor. Details of frequency response of an experimental unit based on simpler circuit of H. H. Scott (Electronics, Dec., 1947, p. 97). Concluded that with upper frequency limit of 6 kc/s., system could not be classed as high-fidelity and that to provide satisfactory control up to 8 kc/s. the more elaborate model of H. H. Scott should be followed.
—**Radiotronics (Aust.), July-Aug., 1948, p. 73.**

Stereophonic sound. Brief explanation of developments in stereophonic reproduction for the home. Newly developed (U.S.) equipment comprises experimental magnetic-tape recording and play-back system. Tape carries simultaneously three channels which are played through properly orientated loudspeakers.
—**Electronics (U.S.A.), August, 1948, p. 88.**

Direct-coupled amplifier. Circuit of direct-coupled amplifier of measured frequency range 10-16,000 c/s., for which high quality is claimed.
—**Wireless World (Eng.), July, 1948, p. 266.**

ANTENNAE AND TRANSMISSION LINES:

Transmission line bridge. Detailed explanation of operation of a system developed in connection with 200 mc. radar work and for use with antennae which were directive broadside arrays. Feeders were twin open-wire, 330-ohm impedance. Bridge described; also matching of receiving arrays. Application of bridge to receiving array.
—**Wireless Engineer (Eng.), July, 1948, p. 215.**

CIRCUITS AND CIRCUIT ELEMENTS:

Common cathode amplifiers. Word "common" used to denote the electrode which is common to input and output circuits. Mathematical treatment of problems arising in connection with common-cathode negative-grid amplifiers, triodes, and pentodes, at about 50 mc. Deals chiefly with effect of inductance in the electrode leads. Matter contained in earlier articles (see **Radio and Electronics** Abstracts, Sept., 1948, p. 26, "Valves") relevant to present discussion and familiarity with such matter assumed. Tables compiled for comparison between triodes and pentodes.—**Wireless Engineer (Eng.), June, 1948, p. 180.**

Shunt equalizers. Formulae and description of method for precise design of shunt equalizers.
—**Wireless Engineer (Eng.), June, 1948, p. 192.**

Thyratron phase-control circuits. A number of Thyratron control circuits for controlling large direct current by small change of direct voltage. Application and respective merits of each circuit discussed.
—**Electronics (U.S.A.), July, 1948, p. 107.**

The "Cascode" amplifier. Reference to an unfamiliar circuit using two triodes, or a double-triode valve, to give high gain at low frequencies. Principal uses: As D.C. amplifier and in amplifier section of voltage regulators.—**Wireless World (Eng.), July, 1948, p. 249.**

Cathode-coupled multivibrator. Simple circuit using a double-triode valve to generate square waves of variable frequency and good waveform.—**Wireless World (Eng.), July, 1948, p. 249.**

Linear saw-tooth generators. New circuit leading to economy in number of valves used in hard-valve type of saw-tooth constant-current type of generator. Charging valve used to assist action of discharge circuit during fly-back.
—**Wireless Engineer (Eng.), July, 1948, p. 210.**

Stable voltmeter amplifier. Multi-range A.C. voltmeters with diode probes require a D.C. amplifier for low input voltages. Circuit of such an amplifier. Meter may be used as an electrostatic D.C. voltmeter or to read R.M.S. voltages in various ranges. Has desirable characteristics such as independence of supply-voltage variations and of valve parameters.—**Wireless Engineer (Eng.), July, 1948, p. 231.**

Parallel-T networks. Design curves and equations for practical conditions.—**Electronics (U.S.A.), July, 1948, p. 114.**

Graphical determination of percentage of harmonic distortion. In place of numerical calculations based on values from characteristic curves, a simpler graphical method is outlined. For use in design of amplifiers or in valve performance analysis.
—**Electronics (U.S.A.), July, 1948, p. 170.**

Resistance-capacitance-coupled pentodes. Choice of operating conditions. Article of practical value, providing solution to questions: (1) Optimum value of plate load resistor for minimum distortion; (2) operating plate current for minimum distortion under any given conditions; (3) how pentode compares with triode, on basis of distortion, for same output voltage; and (4) how critical are operating conditions of a pentode. Measurements taken with valve types 6SF7, 6J7, and 6SJ7.—**Radiotronics (Aust.), July-Aug., 1948, p. 63.**

Timing circuits using Thyratrons 2021 or 2050, suitable for controlling small time intervals. (Reprint of RCA Application Note AN-131.)—**Radiotronics (Aust.), July-August, 1948, p. 70.**

Constant amplification within limits narrower than tolerances of variable elements. Second article. (First article appeared in Philips Tech. Rev. 9, 25-32, 1947. No. 1 dealt with circuits designed to make amplification practically independent of the slope of valves.) Makes use of oscillation at an auxiliary frequency combined with special feedback network system as described in first article.
—**Philips Technical Review (Holland), Vol. 9, No. 10, p. 309.**

FREQUENCY MODULATION:

Discriminator. Circuit of diode counter discriminator for use in home-built F.M. receivers by constructors who have no special facilities for alignment of receiver. Article suggests possible modifications.
—**Wireless World (Eng.), July, 1948, p. 240.**

MATERIALS AND SUBSIDIARY TECHNIQUES:

Luminescence of simple oxide phosphors. Details of investigation of simplest class of luminescent materials, excited by means of cathode rays, with a view to securing data more reliable than that obtainable from more complex compounds.
Electronic Engineering (Eng.), July, 1948, p. 219.

MICROWAVE TECHNIQUES:

Frequency stabilization at E.H.F. Use of gas molecules as resonators. Comments upon a paper, "Frequency Stabilization with Microwave Spectral Lines"—Herschberger and Norton. "RCA Review," March, 1948.
—Wireless World (Eng.), July, 1948, p. 202.

MEASUREMENTS AND TEST GEAR:

Noise generator for receiver measurement. Circuit and details of a noise generator using a diode, which, in this equipment, must have a thoriated tungsten filament. In present case 708A triode used, the control grid being used as anode, and anode proper not connected. Method of operation described.
—Electronics (U.S.A.), July, 1948, p. 96.

Direct-coupled oscilloscope. Circuit and details of construction of oscilloscope of British design suitable for examination of very low frequencies. Uses C.R.T. of high sensitivity developed for radar and requiring low anode voltage of 1 kv. D.C. amplifiers used, consisting of three pairs of push-pull valves in symmetrical arrangement. Oscilloscope response minimum up to 1 mc. or, with less sensitivity, up to 3 mc., as desired.
—Electronics (U.S.A.), July, 1948, p. 102.

Dynamic relay analyser. Description and circuits of an analyser for measuring action of relays under operating conditions. C.R.T. display may be photographed to give permanent records of characteristics of particular relay under examination.
—Electronics (U.S.A.), July, 1948, p. 87.

Resistance deviation bridge. Description of an instrument which may be used to match resistors in groups of $\pm 5\%$. Circuit details. Uses Wheatstone bridge with V.T.V.M. as balance indicator. Particulars of bridge, V.T.V.M., and details of stabilized 12-volt D.C. supply to bridge; also overload protector for meter.
—Electronics (U.S.A.), August, 1948, p. 126.

Polyphase power synchroscope. Description of apparatus and theory of operation. Unit will indicate the state of synchronism of two polyphase power systems. C.R.T. with polyphase deflection as indicator.
—Electronics (U.S.A.), August, 1948, p. 152.

Non-magnetic magnetometer. For measuring field strengths from 100-8,000 gauss, with accuracy of $\pm 2\%$. Sensing element is germanium probe. Principle of operation and circuit.—Electronics (U.S.A.), August, 1948, p. 166.

Multi-frequency synchronizer. Description of apparatus which has a number of applications, such as calibration or measurement. Has been used to produce range markers. Adjustable output of square, rectangular, or impulse waves. Circuit details of four component sections: (1) Input; (2) multiplier; (3) divider; (4) output.
—Electronics (U.S.A.), August, 1948, p. 168.

RECEPTION AND RECEIVERS:

Selectable single side-band reception. Description and circuit of commercially manufactured (U.S.) unit for attachment to communications receiver.
—Wireless World (Eng.), July, 1948, p. 244.

Modulation, inter-modulation, harmonic distortion, heterodyning, frequency-changing, selection, and rectification. An article explaining the action common to all—that is, the operation of an alternating quantity in a non-linear circuit. Illustrated by simple mathematics.
—Wireless World (Eng.), July, 1948, p. 253.

Transceivers for Citizen's Band (U.S.).—See Transmission and Transmitters.

TELEVISION:

Design of TV studio. Description of studio facilities and lay-out of new Columbia Broadcasting System's modern TV studios at WCBS-TV, New York.
—Electronics (U.S.A.), July, 1948, p. 80.

TV receiver. Circuit and constructional details of a receiver with electrostatic deflection, using war-surplus equipment.
—Wireless World (Eng.), July, 1948, p. 251.

Television receiver intermediate frequencies. R.M.A. (U.S.) recommendations specify an intermediate-sound-carrier frequency for commercial television receivers of between 21.25 mc. and 21.9 mc. A detailed analysis to show that these frequencies are too low because of interference from other channels, and that intermediate frequencies above 30 mc. more suitable.
—Electronics (U.S.A.), August, 1948, p. 90.

Television signal generator, picture modulated. Circuit, design, and operation of a signal generator suitable for testing television receivers by commercial manufacturers.
—Electronics (U.S.A.), August, 1948, p. 110.

TRANSMISSION AND TRANSMITTERS:

Citizens' Band (U.S.) transceivers. Part IV of a series (Electronics citizens' radio project). Details of modifications to war-surplus IFF transponder and use of equipment for both mobile and fixed-station purposes.
—Electronics (U.S.A.), August, 1948, p. 76.

Reducing transmission bandwidth. A method of reducing bandwidth for transmitting, simultaneously, two input signals which have been combined into one train of pulses. The two channels are separated by the receiver. Circuit details.
—Electronics (U.S.A.), August, 1948, p. 107.

Two transmitters operating on one antenna. Details of theoretical investigation indicating possibility of using one antenna for two transmitters. Principle: Acceptor and rejector circuits at certain points in feeder systems.
—Electronic Engineering (Eng.), May, 1948, p. 157.

Amplifier instability in transmitters. Analysis of causes of instability, means of detecting such a condition, and methods of elimination.—QST (U.S.A.), June, 1948, p. 19.

Single-sideband suppressed-carrier transmission. Generation of single-sideband signals by phasing method, obviating necessity for filtering out unwanted sideband. (See "Radio and Electronics" Abstracts, July, 1948, p. 15.) Two phase-shift networks with differential phase shift of 90 degrees inserted between source of modulating signals and modulating devices, to produce sets of sidebands which can be combined to cancel one unwanted sideband. Comprehensive explanation of system.
—QST (U.S.A.), June, 1948, p. 16.

ARC transmitter modifications to give 14 mc. output (BC-459-A), improved keying, eliminate ripple (BC-459-A), add N.F.M. (BC-459-A), and to enable use to be made of tuning-eye (BC-459-A).—QST (U.S.A.), June, 1948, p. 61.

A QRP portable transmitter for C.W. or radiotelephone transmission. Compact unit, complete with power supply and antenna-coupling network. 32 watts C.W., 25 watts phone.
—QST (U.S.A.), July, 1948, p. 24.

Transmitter power supply bleeder resistors. Suggestion for reduction in size and cost of resistors through use of valves in neutralized R.F. amplifier stage as bleeders. Grid bias is adjusted so that valves do not draw, under key-up conditions, more than rated plate current. With valves drawing safe amount of current, the bleeder resistor may have reduced wattage rating.—QST (U.S.A.), July, 1948, p. 27.

S.S.S.C. transmitter adapter. Design and construction of adapter, using phase-shift principle, to convert existing C.W. or radiotelephone amateur transmitter to s.s.s.c. transmission.
—QST (U.S.A.), July, 1948, p. 40.

VALVES:

The Dyotron. New type of s.h.f. valve developed in U.S.A. to give unusual stability and wide tuning range. May be used in local oscillators or signal generators up to 3700 mc.
—Communications (U.S.A.), May, 1948, p. 24.

H.F. pentodes in electrometer circuits. Details of investigations to decide suitability of certain British valves (receiving) for use in electrometer circuits in place of special valve usually employed. Valves are EF36 and EF37.
—Electronc Engineering (Eng.), July, 1948, p. 227.

Rectifier storage tube. Description of a cathode-ray storage tube with details of operation and application of memory tube.
—Electronics (U.S.A.), August, 1948, p. 136.

Preferred list of (U.S.) army, navy valves.
—Electronics (U.S.A.), August, 1948, p. 136.

MISCELLANEOUS:

Vibrator design and application. Simple explanation covering operation of vibrators, synchronous and non-synchronous.
—Service (U.S.A.), May, 1948, p. 30.

Vibrator power supplies. Four circuits for operation from 110v. A.C. and 6, 12, 24v. D.C. sources. Article based on "Fundamental Principles of Vibrator Power Supply Design," comp. and pub. by P. R. Mallory & Co., Inc.
—Service (U.S.A.), May, 1948, p. 32.

Noise. Discussion and calculation of effect of electrical noise from various sources, e.g., resistors, valves, and current.
—Electronic Engineering (Eng.), May, 1948, p. 145.

The role of electronics in atomic energy programmes. Address by Professor Sir John Cockroft, F.R.S., at Radio Industries Club on 23rd March, 1948.
—Electronic Engineering (Eng.), May, 1948, p. 148.

High vacuum pumps. History and development. Concluding article. Modern pumps.
—Electronic Engineering (Eng.), May, 1948, p. 163.

Light meter. Circuit and design of a light meter for measuring incident light produced by electric flash-lamps of the capacitor-energized type. Can be calibrated to read directly the correct camera aperture number for colour or black-and-white exposures. Apparatus is compact and battery-operated. May be calibrated by use of standard flash-tube. Uses 929 type phototube and 1L4 type (triode connected) in V.T.V.M. circuit.
—Electronics (U.S.A.), June, 1948, p. 78.

Servicing 16 mm. sound-on-film projectors. Hints for servicing speaker, amplifier, and photo-cell units of older types of (U.S.) projectors.—Service (U.S.A.), June, 1948, p. 14.

Hearing-aids. U.S. types. Design. Performance specifications. Speech-hearing test charts. Specifications based on AMA approvals.—Service (U.S.A.), June, 1948, p. 26.

H-type Adcock direction finders. Design principles for range 3-30 mc. using two-aerial and four-aerial systems. Design considered under headings of sensitivity, directional accuracy, and polarization error. The three main components: (1) Aerial and feeders, (2) coupling circuit, (3) input circuit receiver to the receiver discussed. Factors leading to maximum sensitivity outlined and conclusions summarized.
—Wireless Engineer (Eng.), June, 1948, p. 168.

A Practical Beginners' Course

PART 26

How, then, is this deficiency to be overcome? Simply by drawing more curves. Suppose we label the curve on Fig. 33, "Plate Volts = 250." We now know exactly the conditions to which Fig. 33 refers. Now, we can draw another curve by putting a plate voltage of, say, 300 on the valve and then drawing a new curve of grid volts against plate current. Since we are using the same valve, we can expect the new curve to have the same general shape as the first one, and from what we know already about valves, it should be possible to estimate where the new curve will come with respect to the old one. For example, we know that if the grid bias is kept constant, and the plate voltage is raised, the plate current will increase. This gives us a point on the graph above and to the left of the original curve. In fact, because of the fact stated above, it is easy to see that all points on the new curve must lie above and to the left of the old curve. The new one will therefore occupy this position, and since there is no reason to expect to the contrary, it will have the same general shape as the old one. It will therefore run so that the almost straight portions of the two curves are "parallel." By the same line of reasoning, it can be shown that if we fix the plate voltage at a *lower* figure than 250v., a third curve can be drawn which will lie below and to the right of the original one. Now there is no limit to the number of curves we can draw in this way if we so desire. In fact, theoretically, we would have to draw an infinitely large number of curves in order to describe the behaviour of the valve completely. In practice, though, we do not need nearly as many curves as that, and the usual thing in drawing valve curves of the kind we are describing is to draw them only for 50-volt intervals. A complete set of curves is called a "family" of curves, and unless such a "family" of curves is available, drawn for a range of plate voltages, the information presented is not complete.

The performance curves for a valve are usually known as "characteristic curves," or simply as "characteristics," because they describe the exact character of the valve to which they refer. The particular type we have been discussing is called the "mutual characteristic" because it readily shows the mutual conductance under the varying conditions that can be met in practice. Now, although the family of mutual characteristic curves do tell all that one needs to know about the valve, this form of curve is not always given in books. The reason is that the same information can be presented in two other ways, still by means of graphs, and these ways are often more useful in solving practical problems. The three possible ways of drawing the characteristics look quite different, but it is important to realize that nevertheless the information contained in them is identical. This will be more easily realized when we have examined one of them, and when it is known that if one set of curves is available, the others can be got from it simply by reading off values and redrawing the information already contained in them. As an illustration, we have Fig. 34. This is perhaps the most commonly used way of drawing the characteristics of the valve, and comprises the actual manu-facturer's curves for the type 30, which many beginners have probably used at one time or another. We will describe this figure in a little more detail, but as a clue to the working of this, as compared with the one shown in Fig. 33, it is a good idea for the reader to examine Fig. 34 closely, and then draw it from a curve of grid voltage against plate current. If this is done correctly, there will be no difficulty in recognizing the fact, because the result will look very like Fig. 33. A suitable plate voltage to choose would be 120. The scale of grid volts will need to go from zero to — 12v., and the plate-current scale will need to go from zero to 12 ma., as in Fig. 34.

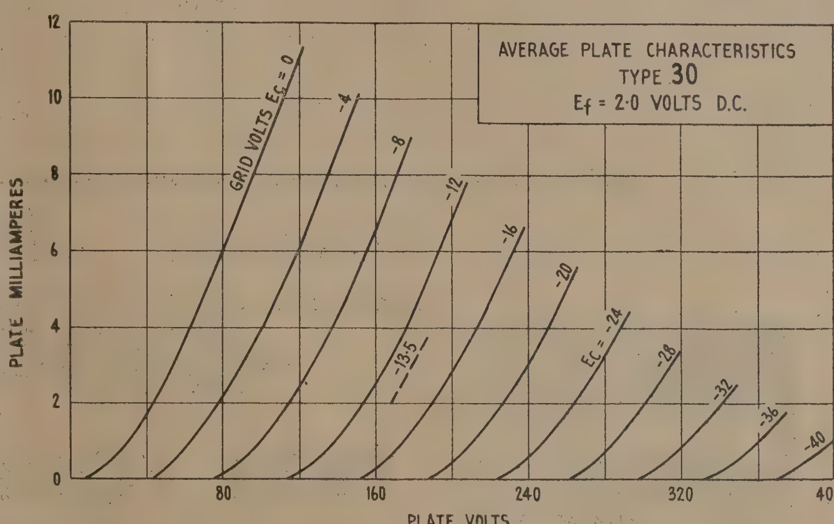


Fig. 34.

THE PLATE CHARACTERISTICS

Fig. 34 is a complete set of the plate characteristics we have described in the previous paragraph. This time, instead of each curve being drawn to represent the behaviour of the valve at one particular plate voltage it is drawn to show what happens under all possible conditions when the grid voltage is set to a particular value. Examination of the graph will show that each curve is labelled with the grid voltage to which it refers. Now, looking at one curve in particular, and forgetting for the moment about all the others, let us examine the axes of the graph. The vertical axis is divided into a scale of milliamps, from 0 to 12. The horizontal scale is labelled "Plate Volts," and is drawn for all plate

voltages from 0 to 400. The graph is therefore able to tell us what plate current will flow if the plate voltage is anywhere from 0 to 400, *as long as we know what the grid bias is at the time.* For example, if the grid bias is zero, we find by looking at the curve labelled "Grid volts = 0" that when the plate voltage is 80, a plate current of 6 ma. will flow. Or, if the plate voltage is 120, the plate current will be 11 ma.

Perhaps the most useful purpose of the plate characteristics from the beginner's point of view is their use for making sure that the valve will not be run at plate currents and voltages in excess of the manufacturer's ratings. For example, the valve books say that a typical operating condition for the 30 is that where the plate voltage is 180, and the plate current is 3.1 ma. Now, suppose we want to use the valve as an amplifier with only 45v. on the plate, we can look up the curve on Fig. 34 and find that with 45v. on the plate, and zero grid bias, the plate current is only 1.8 ma. Thus, it is less than is allowed when the plate voltage is much higher, so that the likelihood of damage to the valve is negligible, even if it is run with no grid bias. This is a useful conclusion, because it enables us to dispense with a bias battery, as long as the plate voltage is only 45.

It is also possible to use these curves to find the amplification factor of the valve, or its mutual conductance. How can these things be found? Let us take the amplification factor first. This, as we have already found out, is the ratio between the plate voltage and the grid voltage changes which will produce the same effect on the plate current. Now, Fig. 34 is drawn for grid voltages at 4-volt intervals. For a start, we can choose a plate current value that is within the range of any two of the curves. For example, we could decide to work out the amplification factor for the plate current of 6 ma. Now, with the plate current at 6 ma., and with zero grid bias, the left-hand curve tells us that the plate voltage must be 80v. If we now change the grid bias to −4v., we find by looking at the curve for this grid bias that the plate voltage needed to make the valve draw 6 ma. of plate current is now 120. We now have the data for working out the amplification factor, for from the curves we have found that a change of 4v. in the grid bias (from 0 to −4v.) can be counteracted by a change of 40v. in the plate voltage, namely, from 80 to 120. The amplification factor is therefore 40 divided by 4, = 10. The mutual conductance, it will be remembered, is a measure of the number of milliamps by which the plate current changes when the grid voltage is changed by one volt, the only other condition being that the plate voltage must remain constant. If the plate voltage is, say, 120v., and the grid bias is −4v., the second curve from the left tells us that the plate current will be 6 ma. If the plate voltage is still 120, but we change the grid voltage to zero, the plate current rises to 11 ma., as indicated

(Continued on page 48.)

OUR GOSSIP COLUMN

SPARE-TIME POET

A collection of poems under the title "Challenge" has been published recently by Mr. Noel Matthews, Advertising Manager of National Electrical and Engineering Co., Ltd., and a writer of verse in his out-of-business hours. These poems are an expression of moods and feelings experienced during his five years' service with the Royal Navy.

A fairly recent arrival from England, "Chris" Matthews was a member of Ford Motor Company's Publicity Staff at Dagenham, Essex, for many years, being the editor of the *Ford Works News*. During the war, a number of his poems were broadcast by the B.B.C., and others appeared in English magazines and in *To-day's New Poets* (Favil Press, London), a collection of wartime verse. More recently, a new poem, "Tribute to Belinda Wright and John Gilpin," was published by Wellington's *Evening Post* during the visit of Ballet Rambert to the city.

"Challenge" is published by A. H. & A. W. Reed Ltd., Wellington. Price 3/6.

* * *

Mr. Ron Greenwood, of National Carbon Pty. Ltd., New Zealand, after having completed a business tour in the United States of America, Egypt, and Singapore, has now reached Sydney on the final stages of his homeward journey.

A recent addition to the rank of proud fathers is Mr. C. P. Clarkson, Accountant to National Carbon Pty. Ltd., who has a bonny son. Congratulations from *Radio and Electronics*.

George Ferris, "That man again," raced through Wellington like the wind—went to Auckland, and ere this is in print will be back in Christchurch once more. What about stopping at *R. & E.* next time for a spell, George?

* * *

Swan Electric Co., Ltd., has now established a Branch at Dunedin with Norman Chiswell as Manager. Norm has had a wide experience both as Sales Manager and later as Stores Supervisor at the Auckland branch prior to transferring to Wellington where, for the past twelve months, he has been Sales Manager and Liaison Officer with Head Office. Our congratulations and good wishes to you, Norman, on your promotion. We know that your many friends in Wellington, including our own staff, will miss your cheery countenance in these parts.

Returning to Swan Electric after an absence of twelve months, Keith Alexander has been appointed to the position formerly occupied by Norm Chiswell. Having been connected with the radio trade for many years, Keith will be no stranger to members of the industry.

* * *

ROMANTIC RADIO PARTNERSHIP ENDED

Whilst proud of her own invention, the name "loud-speaker," Mrs. S. G. Brown considers her husband to have been the most extraordinary inventor in the world, but she once said, "He doesn't know a thing about business and hardly knows a half-penny from a half-sovereign."

This romantic partnership has been severed by the death at the age of 75 of Mr. S. G. Brown, pioneer of radio, who invented the loud-speaker. Partnering her husband in business as well as in the home, Mrs. Brown negotiated all this famous inventor's 1,000 patents, the rights of which were worth thousands, and all of which were in her name.

"One, two, three, Monday, Tuesday, Wednesday," was the interesting conversation of these two, closetted a whole day in different cupboards whilst working on the headphone invention.

Controlling her husband's business took severe toll of Mrs. Brown's health, but though her life was despaired of in 1932, two years later found her controlling nine companies. Now she relaxes at her home at Shepperton, Middlesex, where she has her own zoo and a pig farm, grows orchids and cultivates bananas and pineapples.

* * *

RESULTS OF THE N.Z.A.R.T. "EDDYSTONE" CONTEST

(By courtesy of Messrs. Arnold & Wright)

	Points
Contest Winner:	
"Eddystone" Communications Receiver: Mr. R. A. Dixon, ZL3JT, Brunnerton, West Coast	783
Low Power Phone and C.W. Division:	
1st—Order for £10: Mr. A. M. Montgomery, ZL4HE, Green Valley, Palmerston R.D.	676
2nd—Order for £3: Mr. D. A. Farquharson, ZL4HH, Signal Hill, Dunedin	651
3rd—Order for £2: Mr. A. W. Torrie, ZL2FG, Golden Gate, Paremata	627
4th—Order for £1: Mr. V. R. Jackson, ZL4BO, 47 Lorn Street, Invercargill	596
High Power C.W. Division:	
1st—Order for £10: Mr. C. L. Herbert, ZL1MB, 21 Harapaki Street, Remuera, Auckland	658
2nd—Order for £3: Mr. C. Brittenden, ZL3HC, 153 Otipu Road, Timaru	641
3rd—Order for £2: Mr. M. T. Gabriel, ZL2GL, 239A The Terrace, Wellington	587
4th—Order for £1: Mr. S. G. Waite, ZL1AB, 65 Anzac Street, Takapuna, Auckland	530
High Power Phone and C.W. Division:	
1st—Order for £10: Mr. R. Garrett, ZL1NF, 7 Waipa Street, Birkenhead, Auckland	770
2nd—Order for £3: Mr. S. Langrope, ZL3IA, Lavaud Street, Akaroa	726
3rd—Order for £2: Mr. T. E. A. Nevill, ZL4HP, Moa Creek R.D., Oturehua, Otago	702
4th—Order for £1: Mr. J. W. Potter, ZL1TO, Oratia, Auckland	699
5th—Order for £1: Mr. J. W. P. Bulger, ZL4HJ, 59 Galloway Street, Mornington, Dunedin, W.1	698
6th—Order for £1: Mr. J. R. Keys, ZL3GU, 60 Huxley Street, Christchurch, S.1	695

TOTAL ENTRIES: 45.

These comprised: High Power Phone and C.W., 30; Low Power Phone and C.W., 10; High Power C.W., 5.

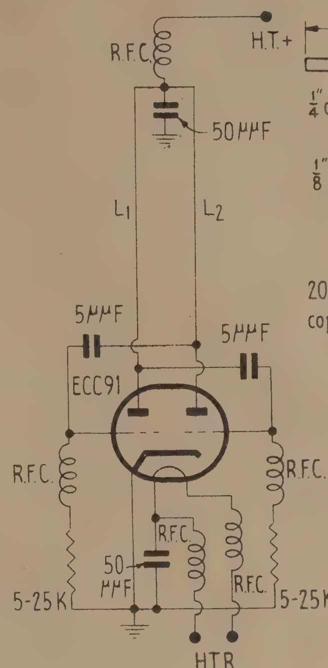
The handing-over ceremony in connection with the receiver will take place in Christchurch when Mr. L. R. Arnold will present to Mr. R. A. Dixon his well-deserved prize. Arrangements for the ceremony will be in the hands of the Christchurch branch of N.Z.A.R.T

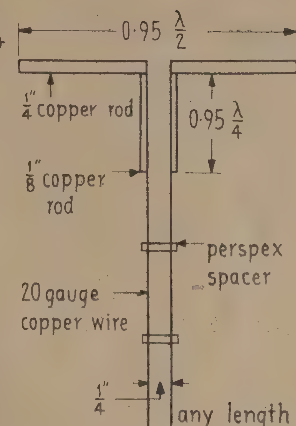
No. 12: THE ECC91 AS A VERY-HIGH-FREQUENCY OSCILLATOR

There are signs that a great deal of interest is being taken in V.H.F. radio communication, of one kind or another, not the least of it being on the part of amateur transmitters. At the moment, the situation with regard to the amateur V.H.F. bands is undecided, but it is clear that of recent months there has been a recrudescence of interest in the higher bands, and that the congested state of the 80, 40, and 20m. bands is in some measure responsible for this. In addition to amateurs, numerous firms and services are finding a use, or rather uses, for short-range radio communication for which V.H.F. is eminently suitable, with its excellent behaviour over line-of-sight paths, and its lack of interference with other radio services at even small distances.

In view of this interest, we are devoting this Experimenter, and intend to allot further space still, to the application of Philips valves to very-high-frequency work. For experimental investigations of all sorts, whether in connection with transmitting or reception, one finds the need for reliable oscillator circuits, and so these pages are being used to describe one highly successful oscillator circuit employing the ECC91, which is a high-mutual-conductance double triode of the miniature or E90 series. Incidentally, the ECC91 is an exact equivalent, electrically, to the American 6J6. It employs a unique type of construction, in that only one cathode is found in it. This is of the relatively large flat type, and one side of it is used for each of the triodes. Of course, this gives the valve a common cathode terminal for both sections, but for certain applications this is a distinct advantage. In particular, for radio frequency circuits where two triodes are used in push-pull, with a common cathode connection, a valve with this type of construction cannot be bettered. The actual cathode sleeve being common to the sections, there is literally no cathode lead that is not common to both sections; in a valve where the sections have separate cathode sleeves, even though they may be very close to each other, there must be some individual cathode lead. Now it is well known that the inability to ground the cathode to R.F. voltages is one of the prime reasons why ordinary valves will not function normally at very high frequencies, especially in circuits where the cathode is the common element of the grid and plate circuits. Thus, a double triode which has a certain amount of cathode lead belonging to each section, individually, will not be so satisfactory a tube at V.H.F. as one in which all the cathode lead that exists is common to both sections.

As an illustration of the point, let us examine Fig. 1. This is an oscillator circuit employing two triodes, or the sections of a double triode, in the so-called "negative resistance" circuit. The grids and plates are cross-coupled by means of condensers, and R.F. chokes are inserted in each grid return to ensure that R.F. voltages are not bypassed to earth by the unavoidable stray capacities in the wiring. Apart from this, the circuit is completed by connecting to each plate the ends of a parallel-line type of tuned circuit. Now, in a push-pull circuit like this, in which the cathodes of the two triodes are supposed to be at earth potential, we have the advantage that any R.F.





Left: Fig. 1.
Above: Fig. 3.
L_1 and L_2, the individual rods of the plate line, are cut to a length suitable for the frequency range desired. The transmitter is converted into a super-regenerative receiver simply by altering the grid-leaks to 500k.

currents flowing from each valve into the common cathode lead are in anti-phase, and so cancel out, leaving the whole cathode lead at zero R.F. potential. Thus, the inductance of the cathode lead does not matter, as it will have no effect on the operation of the circuit, however high the frequency. The argument above clearly does not apply to any cathode leads that may be connected only to one section of the double tube, and in the case where an attempt is made to use the circuit with separate valves, will not apply at all. This is why the ECC91 is so particularly suited to the circuit of Fig. 1. The individual cathode leads are non-existent, thanks to the construction of the valve.

Further examination of the circuit shows that both heater leads have R.F. chokes and bypass condensers inserted in them. This is simply to prevent any loss of power output through resonating of part or all of the heater leads, which are not usually made of low-loss material, especially at V.H.F. The isolation also prevents R.F. from reaching other parts of a complete circuit, which may be run off the same heater supply.

PERFORMANCE OF CIRCUIT OF FIG. 1

In order to demonstrate the performance of the ECC91 at V.H.F. an oscillator circuit was constructed exactly as in Fig. 1. In order to make sure that at reasonably low frequencies the circuit behaved itself according to expectations, the plate line, which is the sole frequency-determining element, was made approximately 8″ long, and H.T. was applied through a protective resistor of 25,000 ohms. A plate current meter was

used, and in addition, a grid-current meter, 0–10 ma., was inserted between the common point on the grid leaks and chassis. These meters are both necessary in investigating a circuit of this kind, especially when a small valve is used, for it is most important to see that the ratings are not exceeded. In passing, it may be stated that as well as the information given in the Philips Valve Manual, the following ratings apply, and if valve life is a consideration, should be adhered to strictly. The maximum plate input power is 9.5 watts, the maximum plate current is 30 ma., and the maximum grid current is 16 ma. These figures are for *both* sections.

The spacing of the plate lines was ⅜", which is convenient, as it does not require the line spacing to become closer at the valve end in order to reach the plate pins. With the 8" line, the frequency of oscillation was approximately 150 mc/sec., which is low enough for good efficiency, and forms a suitable starting point for experiments in making the frequency of oscillation higher. At this frequency, which is well within the highest frequency mentioned in the valve manual, the efficiency was very good, and it was possible to apply the full plate voltage of 300 without the 30 ma. maximum plate current being exceeded. The next step was to shorten the lines considerably, in an attempt to raise the frequency. For a start, a line only 2½" long was used, made as in the circuit diagram. The frequency was found to have increased to just over 250 mc/sec., still with quite good efficiency, so the line was left at that, and further shortening done by means of a short-circuiting bar, soldered across the line. The results obtained were rather surprising, to say the least, in that oscillation was still obtained with only half an inch of line left, and the frequency was found to be 590 mc/sec.! It could hardly be claimed that the efficiency at this frequency was very high, but there it was! Not only did the circuit still oscillate, but it showed none at all of the vices usually associated with attempts to reach the limiting oscillation frequency of a valve. No R.F. was observable at any point which was supposed to be at earth potential, and it was possible to touch any part of the circuit except the plate line without affecting the plate or grid current. Better than this, it was possible to couple quite appreciable amounts of power out of the oscillator without putting it out of oscillation. An interesting point in connection with loading an oscillator which has open-wire lines as the tuned circuit is that the plate current will not rise at first, even though power is being absorbed in the load. The reason for this is that when no power is being taken from the circuit intentionally, there is considerable power lost by radiation. Thus, until the aerial or dummy load is drawing more power from the circuit than it was previously losing by direct radiation, there is no rise of plate current.

Having established that the ECC91 would function almost to 600 mc/sec., it was decided to carry the experiment a little further, by seeing what the circuit would do at some high frequency, considerably lower than the maximum, yet much higher than the 250 mc/sec. figure quoted in the manual. Purely for convenience, it was decided to make further investigations at about 350 mc/sec. At this frequency, the lines were 2" long, not counting the socket lugs, and were supported at the valve end by the lugs themselves, and at the shorting bar end by a single midget stand-off insulator. The lines therefore sloped downwards to the valve socket, but this had no adverse effect on the operation. In fact, the lack of insulation at the plate end was certainly beneficial since losses in this part of the line, where high R.F. voltages are to be found, could reduce the efficiency badly.

FREQUENCY CONTROL

At this stage, it was decided that some easier method of frequency control than soldering a shorting bar on to the lines was desirable, so it was decided to try the effect of a shorted turn of copper, moving into the field of the lines near their high-potential ends. A small ring was made by cutting a piece ⅛" long from a length of ½" diameter copper tubing. The ring was then filled with a piece of insulating material (ordinary ebonite was used quite successfully) through which a small hole had been

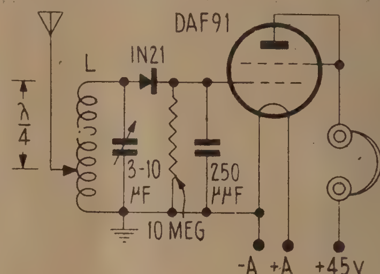


Fig. 2. A simple monitor for the transmitter. The crystal detector can be a 1N21, or other silican crystal, but NOT a germanium crystal, which will not work well above 100 mc/sec.

drilled in the centre. Some threaded brass rod was screwed into the hole, and the whole arrangement was mounted on the chassis by soldering to it a brass collar, threaded to take the shaft of the tuning ring. In this way, the plane of the ring is held parallel to the chassis, and screwing the mounting shaft brings it closer to the plate lines. Since the ring is insulated, no harm is done when and if it touches the lines, so that no limitation of the movement need be made. The degree of frequency variation achieved by the use of the ring will vary according to the position at which it is mounted along the line. Maximum effect will be had when it is closest to the plate end, and the tuning range can be reduced by moving it nearer the shorting bar. In our case, it was mounted with its centre ½" from the plate end of the line. Needless to say, it is necessary to preserve symmetry by placing the centre of the ring on the centre-line between the line rods.

This method of frequency control was found to function excellently. Its action was smooth, and caused no peculiar effects whatever. In the oscillator whose proportions we have described, it caused a total frequency variation of 8 mc/sec., about a centre frequency of 350 mc/sec. Thus, any oscillator using this circuit can be completely controlled as to frequency by using the shorting bar as a coarse control, and the ring for continuous variation. The losses introduced by the ring were negligible. Over the whole range of movement, there occurred a hardly perceptible change in either grid current or unloaded plate current.

OPERATING CHARACTERISTICS

So far, little has been said about the effect of various values of grid leak. This, apart from the R.F. chokes, is the only value that can have much effect on the operation, the circuit being such a simple one. It will be noticed that the maximum allowable grid current is 8 ma. per section, or 16 ma. total. However, on the higher frequencies it was found that a much smaller grid current than this was desirable from the point of view

of efficiency, and in order to keep the unloaded plate current down to a reasonable figure. With 25k. grid-leaks for each section, and a plate voltage of 250, the unloaded grid current was 3.1 ma., dropping to 1.8 ma. at full load. At the same time, the unloaded plate current was 25 ma., and the full-load plate current 30 ma. Here it should be noted that it was possible to load the oscillator much more heavily by reducing the grid-leaks to 10k. each, causing the unloaded grid current to increase to some 8 ma., but if this was done, the maximum plate current of 30 ma. was exceeded. Under the conditions outlined in detail above, it was possible to draw from 2 to 3 watts from a hairpin coupled to the plate line.

It is not recommended that the ECC91 be run in excess of its ratings, nor is it necessary to do so to get enough power into an aerial for any line-of-sight communication, but it is interesting to note that one need not fear accidental overloads, even if they are quite protracted. In an overload test, the circuit was run at 18.5 watts input (265v., 70 ma.) for 5½ hours without any sign of distress. After this, it was returned to its normal operating conditions and functioned exactly as it had been doing before the overload test.

OUTPUT COUPLING

There is no difficulty in coupling power out of the oscillator by means of the usual hairpin type of coupling loop. This should have the same centre-to-centre spacing as the plate lines, and should have its loop approximately half way down the lines. Arrangements should be made for varying the spacing between it and the lines. This can be done most easily by bending the hairpin. It will be found that there is a critical point beyond which increasing the coupling between the hairpin and the lines decreases the amount of power taken from the oscillator instead of increasing it. If it is desired to modulate the oscillator, the coupling should be equal to or less than this critical value. If it is greater, the oscillator modulates downwards, but otherwise it modulates in the normal manner. In modulating the oscillator experimentally, a single EL41 was used as a simple Heising modulator, the usual bypassed dropping resistor being employed between the modulation choke and the oscillator. Although not an exact impedance match for the EL41, a high level of modulation was obtained before distortion and over-modulation set in.

RECEIVERS FOR OSCILLATOR TESTING

In experimental work of this nature, it is very desirable to have a receiver with which to listen to the modulated output. The simplest type of receiver, that is really no more than a monitor, but which will be found useful in all V.H.F. experiments, is shown in Fig. 2. This is nothing more than a crystal detector with a tuned

(Concluded on page 47.)

TRADE WINDS

Messrs. A. C. Kitson & Parker, Ltd., London, have presented an illuminated address to Messrs. Radio (1936), Ltd., in appreciation of the latter's generosity and good-will in sending, over a period of years, food parcels to the former company. The address, as reproduced above, is a fine example of English artistry in colour design, and it occupies a prominent position in the office of Mr. Clifton Lewis.

* * *

RADIO TRADERS' ASSN. NEWS

The Auckland Provincial Radio Traders are actively canvassing the idea of a distinctive badge for use in all Radio Traders' publicity. The idea is to identify with the public the traders who conform to the standards set by the Association for its members.

Such a badge could be adopted nationally and become widely known as the trade-mark for the Association's members and symbolic of good service, etc. Undoubtedly it would serve to create confidence on the part of the public.

* * *

General Manager F. S. Taylor presided over the Annual Conference of the National Electrical and Engineering Co., Ltd., recently held in Wellington. Amongst those present Were Managing Director Wilson Jones, and Branch Managers E. N. Tewsley (Auckland), R. S. Donovan (Wellington), J. M. O. Walker (Christchurch), and D. H. Shortt (Dunedin).

Discussion covered country-wide company activities for the past year, and a programme of future trading policy was formulated.

From the July, 1948, number of *Electronic Engineering,* we learn of the establishment of a London Club-office for overseas businessmen. Buyers from abroad now have at their disposal in London a combined club and office with use of secretaries and many other amenities. Organized by International Business Services Ltd., at 14 Arlington Street, Piccadilly, showrooms are provided for British export houses, thus bringing the buyer and seller into close contact at one centre. This should prove a boon to New Zealanders making short business trips to England.

* * *

Inductance Specialists 1948-9 Catalogue is now available. Made in broad sheet style for wall display and ease of reference, it includes a comprehensive range of R.F. inductances of all kinds.

* * *

Philips new "Global Radio Log" is now available. This lists the principal short-wave stations of the world and the Australian and New Zealand broadcast stations.

* * *

Now available, the Lamphouse Annual 1948-9 includes the usual comprehensive range of stock lines and data for the home builder, etc. The price, inclusive of postage, is 1/3.

* * *

A NEW WIRE ENAMEL

In Vol. 8 No. 1 of *Westinghouse Engineer* we note an announcement by Westinghouse Electric Corporation of a new synthetic wire enamel. This promises further improvements over those used at present. It is approximately equivalent to the best mechanically, says Westinghouse, but is several times better than others in thermal stability. On very small wires in particular, where the film thickness is only a small fraction of a mil, it has shown far more uniform coverage and better ability to withstand high mechanical pressure between adjacent coils. According to report, it has excellent resistance

to the powerful solvents now used in insulating varnishes, and is far the most resistant to Askarel of any enamel known, although experience is yet insufficient to recommend its use in such liquids.

* * *

Arising from a court case held at Whangarei in August last, it has been brought to notice that the onus is on the owner of a radio receiving set to notify the Post and Telegraph Department should his set become unserviceable and remain so. Otherwise the owner is liable for the current licence fee which the Department will continue to charge until such time as notified of the unserviceability or dismantling of the set. Failure to pay the licence fee or notify the Department that the set is no longer in use renders the owner liable to prosecution and fine.

* * *

PULSE-TIME MODULATION

Recently the Australian P.M.G.'s Department placed an order with Standard Telephones and Cables Pty., Ltd., for the supply of terminal and repeater equipment for pulse-time modulated microwave radio-telephone links. This equipment will be manufactured in S.T.C.'s Sydney factory.

The PTM equipment to be installed in Australia as a result of the present contract provides a 24-voice-channel radio link system which has been developed primarily for use with telephone circuits. It is suited for extension, replacement, or supplementing of wire and cable facilities. In most cases use of this radio link will be more economical than equivalent service by conventional means. It is especially advantageous where terrain conditions or water paths make wire installations costly or impracticable.

This equipment is the result of 20 years of research and development within the International Telephone and Telegraph System, with which S.T.C. is affiliated. The first IT and T microwave link was developed about 1930, and was installed on a commercial basis in 1934 for service across the English Channel.

The present system uses the pulse-time method of modulation with time division multiplex. The primary carrier of energy is a microwave radio-frequency signal utilizing highly-directed beams. These signals may be amplified by repeater stations located at appropriate points along the radio link circuit. The microwave radio frequency carrier is modulated by pulses which simultaneously carry the intelligence and provide a means for multiplexing 24-voice-channels by time division on the same radio-frequency carrier.

The use of the pulse-time method of modulation offers many advantages over conventional methods of modulation. An improved signal-to-noise ratio characteristic is obtained by virtue of the wideband transmission. Cross-talk effects between channels are minimized, since non-linearities are unimportant. Limiters and other noise-reducing devices may be utilized effectively to take advantage of the constant amplitude characteristics of the signal.

In the time-division system of multiplexing, each channel is allocated one twenty-fifth of the total time interval for the transmission of its speech energy, plus a guard time. The twenty-fifth interval is used to re-establish the reference time through the transmission of a distinctive marker-pulse. During the time allocated to a particular channel a short pulse is transmitted. When no speech energy is applied to the channel input, this pulse is positioned at the centre of the time interval. Speech energy modified the position of the pulse about the centre within the channel limits. The energy in this pulse train is applied to the radio frequency equipment for controlling the emission of a corresponding radio frequency pulse train.

The micro-wave link consists of one terminal at each end of the telephone or communication circuit, plus the required number of repeater stations appropriately spaced along the radio link path. The number of repeater stations required and their spacing is dependent upon local conditions, but an estimate of three transmission hops per 100 miles may be assumed.

A terminal consists of a multiplex modulator, a multiplex demodulator, and a micro-wave transmitter and receiver with their associated antenna systems.

A repeater station consists of a micro-wave transmitter and receiver, with their associated antenna systems, for each direction of transmission.

N.Z. RADIO MANUFACTURERS' FEDERATION NEWS

President's Premonition Proves Fortunate

On the evening following the recent meeting of the National Executive of the N.Z. Radio Manufacturers' Federation, the Federation President, Mr. William J. Blackwell, and the Secretary were drafting a Press statement, as requested by the Executive, for release on the following day stressing the urgent need for the immediate restoration of previously-made cuts in broadcasting hours. Half way through the task, however, Mr. Blackwell was seized with a premonition and decided that the Press statement should be withheld for a further day. Either the premonition was most timely and fortunate or the feelings of the Federation were willed to the authorities since some twelve hours later the Minister in charge of broadcasting, Hon. F. Jones, announced the full restoration of broadcasting hours.

Manufacturers' Publicity Plans Well In Hand

Plans for the national publicity campaign being sponsored by the N.Z. Radio Manufacturers' Federation are now well in hand. Since the time of the last report in this journal the tentative plans have come to fruition and the campaign is to be launched on 1st November, 1948. The Goldberg Advertising Agency Ltd., Wellington, has been appointed the Federation's official advertising counsel for the campaign.

Radio Manufacturers To Confer In Rotorua

Meeting in Wellington recently, the Executive of the New Zealand Radio Manufacturers' Federation completed initial arrangements for the Annual General Meeting of the Federation which will be held in Rotorua on Wednesday and Thursday, 17th and 18th November, 1948.

Entertainment plans are in the hands of the host Group, Auckland, a most interesting programme having been drawn up by the Federation President, Mr. William J. Blackwell, and the Auckland Group Chairman, Mr. D. T. Clifton Lewis. The plans for the Conference, which will be attended by some 20 to 25 Federation members, will include a Golf Tournament on the afternoon of Thursday, 18th November.

On present indications the Conference promises to be extremely lively and valuable to all members of the trade, especially in view of the many matters of national importance at present being actioned by the Federation.

N.Z. RADIO TRADERS' FED. NEWS

Auckland Provincial Radio Traders' Assn.

Twenty-one members attended the recent annual general meeting under the presidency of Mr. S. D. Mandeno. In the course of the chairman's opening remarks, he stressed the need for still greater membership and dwelt on the proposals in this regard now before the Federation. Widely discussed was the period of guarantees and it was resolved to approach the manufacturers in the endeavour to arrive at some solution of this oft-discussed problem. Greeted with enthusiasm was the suggestion (already considered favourably by Wellington Association) that an Association Badge or Symbol be adopted for use by members on letterheads, displays, etc. This matter is to be referred to the Federation for final opinion.

Officers elected for the ensuing year are: President, Mr. S. D. Mandeno; Vice-Presidents, Messrs. D. J. Reid and S. B. Christie; Executive Committee, Messrs. D. T. C. Lewis, T. B. Parkinson, and W. E. Hunter; Auditor, Messrs. Chambers, Worth, and Chambers; Secretary, Mr. J. P. Buddle representing Messrs. J. F. Buddle and Son; Representative on Council of the Chamber of Commerce, Mr. S. B. Christie; Member of Apprenticeship Committee, Mr. S. B. Christie; Member of Seddon Memorial Technical College Advisory Committee, Mr. J. Orbell; Member of Seddon Memorial Technical College Electing Committee, Mr. S. D. Mandeno; Delegates to Radio Traders' Federation: It was resolved—That the Executive be empowered to appoint its own delegates to the Council of the Federation from amongst its members, at its discretion.

PORTABLE COMPETITION

By the time this issue appears on the news stands there will be only a few days left in which intending competitors can post entries. ***Post your entry before it is too late.***

* * *

LABORATORY PROTOTYPES

Readers who may wish to purchase the laboratory models of equipment described in these pages are invited to write to us for details of prices, delivery, etc. At the moment we have for disposal the original of the "New 6A3 Amplifier" described in the June, 1948, issue.

"RADIO AND ELECTRONICS"

Back and current numbers of "Radio and Electronics" may be obtained from—

Te Aro Book Depot, Courtenay Place, Wellington.
S.O.S. Radio Service Ltd., Queen St., Auckland.
Tricity House, 209 Manchester St., Christchurch.
Ken's Newsagency, 133–135 Stuart St., Dunedin.

5″ OSCILLOSCOPE

(Continued from page 15.)

to cover the tube completely. The most important part is the parallel part, however, and if this is enclosed, a great reduction in magnetic hum can be expected. If this is not enough, the next step is to get some heavy iron or steel plate, and make a box which totally encloses the power transformer. To be effective, this shield should be at least 1/16″ thick, and preferably ⅛″ thick. In even bad cases, the amount of screening described should be enough to allow proper operation of the 'scope.

Before deciding on the style of construction, it should be realized that there are at least two other approaches to the problem of magnetic hum. One is to mount the power transformer on the side or back of the C.R.T. case, *outside*. This is rather a nuisance, in that it spoils the look of the instrument, but will help considerably, because it both removes the source of the trouble further from the tube, and at the same time gives a certain amount of automatic shielding. Another method is to put the power supply on an entirely separate chassis from the tube, and run a cable between the two units. If this is done, a single high-voltage lead can be taken from the power supply chassis, and the complete voltage divider and shift circuit placed in the tube unit. This has the advantage of keeping all the controls at the tube, which makes for convenience in operation. Since the filtering has already taken place in the power supply unit, the leads to the tube unit can be as long as desired.

Apart from the magnetic hum problem, there is nothing in the unit that calls for special care. Of course, the leads to the deflecting plates should be as direct and short as possible, which means that the four terminals should be placed on the back of the tube unit. The tube socket can be close to the back of the case, so that just enough space is left for installing the blocking condensers between it and the terminals. As well as the plate terminals, there should be an earth terminal, which is used both for grounding any deflection plates that need it, as described above, and for connecting the 'scope chassis to that of the gear that is being examined. A common earth point is most important. As mentioned above, the C.R.T. filament winding has been left off the circuit diagram, on purpose, so that intending builders will not feel bound to using either a separate transformer, or a third winding on the main one. Either scheme is equally satisfactory, and it should be remembered that the remarks above on the insulation of the rectifier filament winding apply equally to the tube's filament winding.

USING THE 'SCOPE

Since there are so many uses for a 'scope of this nature, we have thought it best to leave a detailed discussion of its use until after the amplifier and time-base unit has been described. It will then be possible to list a number of the applications which require the use of the extra unit, as well as those which do not, and to explain in more or less detail just how the tests are carried out. In the meantime, readers are referred to the many books which give details of 'scope tests and uses. Amateur transmitters, in particular, will find descriptions of most of the tests in connection with transmitters described in the various Amateur Handbooks. Next month we will contiue with the circuit and constructional details of the amplifier and time-base unit.

(To be continued.)

PHILIPS EXPERIMENTER

(Continued from page 43.)

input circuit, and a quarter-wave aerial tapped near the earthed end of the tuning "coil." With the audio amplifier shown it will be capable of receiving transmissions from the oscillator up to 20 or 30 yards away, and is a useful check for modulation quality, and, if a micro-ammeter, or even a 0–1 ma. meter is placed in series with the crystal detector, can be used as a field-strength meter for adjusting aerials. Alternatively, for communication purposes, trials showed that the oscillator circuit of Fig. 1 made a really outstanding super-regenerative detector, simply by placing headphones in series with the plate lead to H.T., and by raising the value of the grid-leaks to 500k.

We therefore have in the oscillator circuit an excellent basis for a trans-ceiver operating on any band between 150 and 500 mc/sec. With a plate supply of 200v. for the oscillator, the super-regen. action was exceedingly smooth, and the tuning, by means of the shorted turn, was just as effective, and as long as the valve was shielded, introduced no hand-capacity effects whatever. If it is desired to make the receiver completely portable for field tests, it will be found to work well with only 90v. of H.T. However, with this lower plate voltage, it is necessary to replace the 5 $\mu\mu$f., grid coupling condensers with Philips trimmers, so that one of them can be used to get accurate circuit balance. The procedure is to set one of them so that the capacity is estimated at about 5 $\mu\mu$f., and then to adjust the other in very small steps until super-regeneration, without fringe-howl, is obtained over the whole tuning range. This is not a difficult matter, and once the right adjustment is found the trimmers can be sealed in position and left.

AERIALS FOR THE OSCILLATOR.

At frequencies as high as this, an infinite variety of aerials and arrays could be used. One very satisfactory one, which has quite wide-band properties owing to the fairly high ratio of diameter to length, is shown in Fig. 3. The quarter-wave transformer is adjusted by varying the spacing until, with a given coupling to the oscillator, maximum power is radiated. It will then be found that the standing waves on the untuned line are quite low in amplitude. This can be checked by running the finger along the line, and noting the variation of oscillator plate current as this is done. When the aerial has been matched to the line by the above method, no further aerial adjustment is necessary, and all that has to be done is to vary the coupling hairpin until the oscillator is correctly loaded.

In the whole of the above, no specific frequency band has been mentioned. It is a simple matter, by using Lecher lines, to measure the frequency, and to set the oscillator to any desired band by adjusting the length of the plate lines.

* * *

CLASSIFIED ADVERTISEMENTS

Rates are 3d. a word, with a minimum charge of 2s. Advertisements must be to hand in this office not later than the fifteenth day of the month in order to be published in the issue appearing about the middle of the following month.

While all care will be taken, no responsibility can be accepted for errors. Advertisements should therefore be submitted either typed or printed in block letters.

VOLUME EXPANDER

(Continued from page 7.)

level increase when the gain automatically comes up due to the normal action of the circuit.

It should be realized from the start that not all records are suitable for the application of an expander. For instance, a record that is uniformly loud will hardly be affected, and the same applies to one that is uniformly soft. Also, swing music does not lend itself well to the use of volume expansion, because the peaks of volume are usually of such short duration. Undoubtedly, the most satisfactory kind of music is orchestral and straight vocal music. As an example of what is meant, the Minneapolis Symphony Orchestra's recording of the waltzes from *Der Rosenkavalier* by Richard Strauss (H.M.V. D.A.1507 and D.A.1508) is one that is admirably suited to volume expansion. Gradual crescendo and diminuendos, and climaxes which build up from a low volume level are brought out in most realistic fashion, and it is not until the same music is heard without expansion that its full benefit is appreciated.

*"An Improved Volume Expander": "Radio and Electronics," Vol. I, No. 3, June, 1946.

BEGINNERS' COURSE

(Continued from page 38.)

by the left-hand curve. We have therefore found that four volts change in grid bias causes $11 - 6 = 5$ ma. change in plate current, when the plate voltage is held at 120. Therefore, one volt change in grid bias would have caused the plate current to increase by $5/4 = 1.25$ ma. The mutual conductance must thus be 1.25 ma. per volt. From this it can be seen that we can do exactly the same things with the plate characteristic curves as we can with the mutual characteristics. This is because, as we stated in our last instalment, the two sets of curves are simply different ways of presenting the same information.

(To be continued.)

HIGH-FIDELITY TUNER

(Continued from page 30.)

tuning, whereas in fact it is not. In the wide positions, the pass band is so wide that there is no accurate means of tuning to the centre of it, so that the method of tuning in the narrow position and then switching over is the only practicable one. This is the only precaution that need be taken in the operation of the tuner, which in all other respects is conventional. With a final word to the effect that the results from this circuit have to be heard to be believed we can leave the idea and the circuit to our readers, in the hope that some at least will feel impelled to try it.

ATTENTION AUSTRALIAN READERS

We are pleased to advise our Australian readers that arrangements have been made whereby annual subscriptions and copies of back numbers of "Radio and Electronics" may be obtained from

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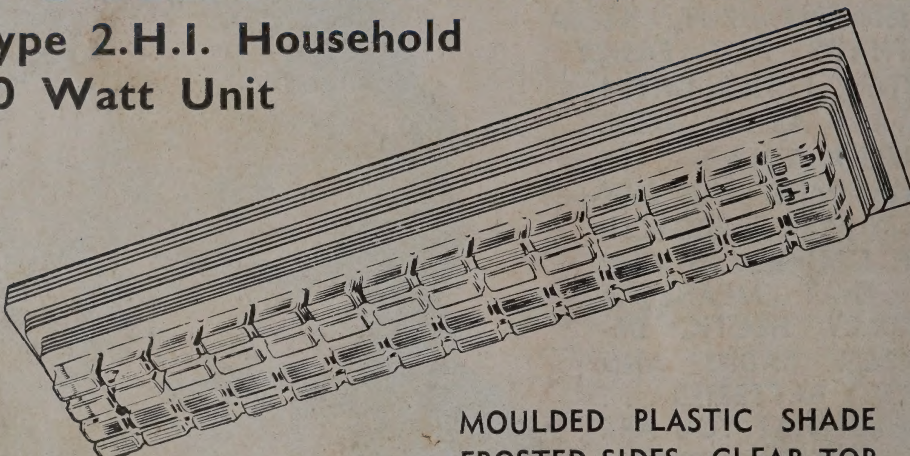

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